17th Australasian Fluid Mechanics Conference
Auckland, New Zealand
5-9 December 2010

An Experimental Investigation of Pressure Loss in Canvas Fire Hose

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Abstract

The NSW Rural Fire Service (RFS) of Australia uses canvas "lay flat" fire hose to deliver water at an incident. A single "rule of thumb" figure for the estimated pressure loss over a length (approx 30m) of canvas hose is used. This figure is a general average based off figures published by the hose manufacturer. These figures in turn were obtained from tests as per the Australian Standard AS-2792, which requires the hose to be under defined conditions. However, these conditions do not reproduce what is happening in a real-life fire-fighting situation. One example of the non-realistic conditions is the hose being laid completely straight. For, even in the most ideal situation, the hose still has to curve down from the back of the truck to the ground. In this experimental investigation, a test rig was set up to measure pressure loss over a length of canvas fire hose under a range of situations similar to how the hose will be laid in an actual scenario. The measured losses were found to be significantly greater than results published by the hose manufacturer, with the difference increasing with more severe bends and twists in the laid hose. The difference also varies with hose diameter. On the other hand, hose age was found to have a negligible effect on losses, contrary to expectation.

Introduction

In this work experiments are performed to investigate the actual pressure losses in canvas fire hose used by the New South Wales (Australia) Rural Fire Service (NSW RFS).

The NSW RFS uses a "rule of thumb" when quick calculations are made for pumping operations. Assuming there is no height change throughout the length of the hose the "rule of thumb" is 100kPa of pressure loss per "length" (about 30m) of hose regardless of configuration or hose size; i.e. 3.33 kPa/m [3]. This 100kPa-per-"length" is based on figures published by the hose manufacturers. The manufactures test all their hoses in accordance with Australian Standard AS-2792 – Fire Hose – Delivery Layflat [5].

This standard states that the hose must be under the same conditions all the time for every test. These test conditions require a completely straight hose under specific flow rates and pressures. Although the standard ensures consistency in the manufacture of all hoses and that they all preform to the same standard and quality, it is set under lab conditions and does not give a true indication of how the hoses will perform and the actual losses in real-life conditions experienced in a fire-fighting scenario.

There has not been much work done on canvas fire hose. The pressure loss data used by the NSW RFS are from tests conducted by hose manufacturer according to AS-2792 [3,5]. Figure 1 shows a representative set of such data (for 38-mm-diameter unlined hose). Related to this topic is reference 6 on losses in pipe flow, while reference 4 explains how nozzle manufacturers make their hoses to perform at specific nozzle pressures, not pump output pressure. This becomes an issue as a nozzle will not perform at its best efficiency when only based on nozzle pressure.

In this work, pressure loss will be determined in terms of hose size, age, and hose-lay configuration. Comparison with the "rule of thumb" and figures from hose manufacturer from tests conducted according to AS-2792 will be made.

Equipment and Experimental Set-up

Tests were conducted at a local NSW RFS station in Australia. Measurements of flow rate and pressures (gauge and differential) were done from the back of a Category-1 RFS tanker whose photograph is shown in figure 2. Percolating hose similar to that of figure 3 was used, with 3 sizes: 25-mm diameter, 38-mm, and 65-mm. These are the hose sizes used by the NSW RFS. Two nozzles were used: a 25-mm Dial-A-Jet nozzle [2] for the 25-mm hose, and a 38-mm Akron nozzle [1] for 38-mm and 65-mm hoses (a reducer is also used with 65-mm hose). The experimental set-up is shown in figure 4. A Dobbie Bros pressure gauge is used for measuring nozzle pressure (P2 in figure 4); pressure difference between the tanker pump's outlet and the nozzle's inlet (P1 – P2 in the hose set-up's figure 4) is measured with a Buddenberg differential pressure gauge. Flow rate was measured using a stop watch and a water drum. Figure 5 shows photo of a nozzle with pressure line attached (for pressure P2 in figure 4) and the water drum, and figure 6 is a photo of the back of the tanker showing hose connection and pressure line attached (for pressure P1 in figure 4). Three hose-lay configurations are tested: straight, moderate bends, and severe bends. In straight configuration, the hose was laid as straight as possible on the ground, but it still needs to curve from the back of the tanker down to ground level. Figure 7 shows the hose configuration for moderate bends and severe bends, respectively. Figure 8 is photo of the whole set-up for a severe-bend case.

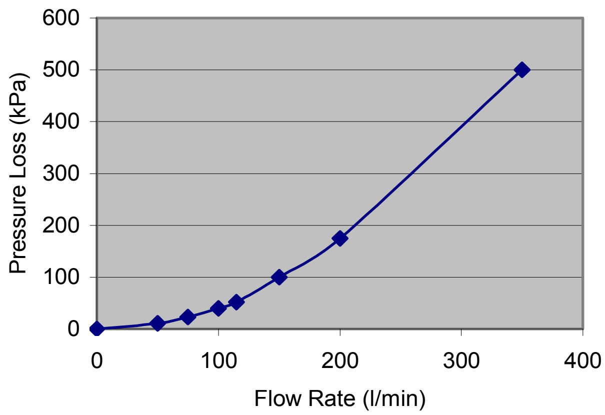

Figure 1. Pressure drop over a "length" of hose (30m) versus flow rate for a representative case of 38-mm-diameter unlined hose. Data from hose manufacturer from tests complying with Australian Standard AS-2792.

Figure 2. Photo of a Category-1 RFS fire-fighting tanker.

Figure 3. Percolating hose used to deliver water for fire-fighting.

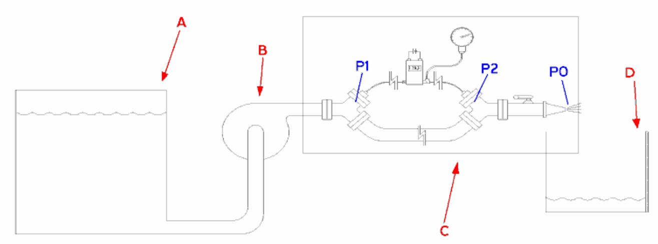

Figure 4. Hose-test set-up. **A** – Supply water reservoir (on tanker), **B** – Pump (on tanker), **C** – System (hose configuration, couplings, nozzle, pressure lines and gauges [upper branch between P1 and P2]), **D** – Water tank (for flow rate measurement), **P1** – Pump outlet pressure, **P2** – Nozzle pressure (kept at 700 kPa gauge), **P0** – Atmospheric pressure (0 kPa gauge).

Figure 5. Photo of a nozzle with pressure line attached (for pressure P2 in figure 4) and the water drum.

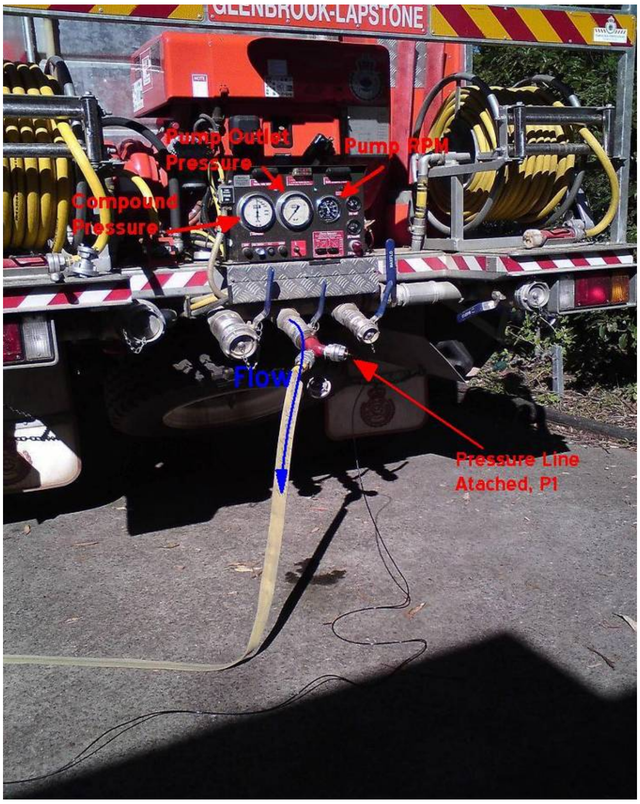

Figure 6. Photo of the back of the tanker showing hose connection and pressure line attached (for pressure P1 in figure 4).

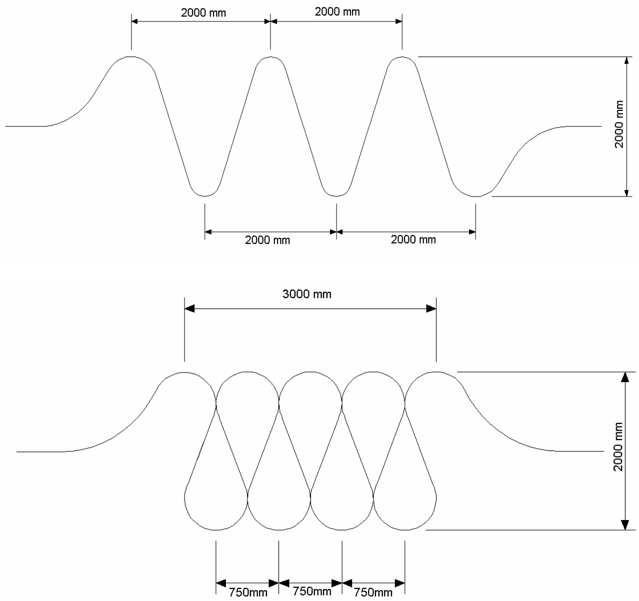

Figure 7. Hose-lay configuration for moderate bends (above) and severe bends (below).

Figure 8. Photo of a test set-up with hose having severe bends.

Results and Discussion

Measurements of pressure drop were conducted for the following variations in 4 runs of repeated experiments

3 hoses with diameter 25 mm, 38 mm and 65 mm respectively; 2 age conditions: new (less than 6 months old) and used (more than 3 years old); 3 hose-lay configurations: 1 – straight, 2 – with moderate bends, 3 – with severe bends.

Pressure P2 at nozzle inlet (see figure 4) is always maintained at 700 kPa (gauge). This keeps the flow rate constant for each hose as its bends become more severe. However, flow rate does vary with hose size, because two different nozzles (plus a reducer) were used to suit the hoses. Using different nozzles to suit the hoses is in keeping with the common practice. Thus, flow rate is 75.2 l/min for the 25-mm hose, 117.3 l/min for 38-mm hose, and 124.4 l/min for 65-mm hose.

Figure 9 shows results for the above conditions. From this figure, the following points are seen

- Pressure increases significantly as hose bends become more severe, especially with smaller-diameter hoses
- Age does not seem to play a significant role
- Rule-of-thumb figure of 3.33 kPa/m is significantly lower than the pressure drop in 25-mm hose, but larger than that in 38-mm and 65-mm hose

The measurements in figure 9 are also averaged and shown in figure 10.

In similarity with flow in rigid pipes, the averaged pressure-drop values in figure 9 are non-dimensionalised in the form of a friction coefficient f defined as

$$f = [2d/(\rho V^2)]\ (\Delta P/l) = [\pi^2/(8\rho)]\ [d^5/Q^2]\ (\Delta P/l)$$

where $(\Delta P/l)$ is the pressure drop per unit length of hose, d the hose diameter, ρ water density, and Q the flow rate.

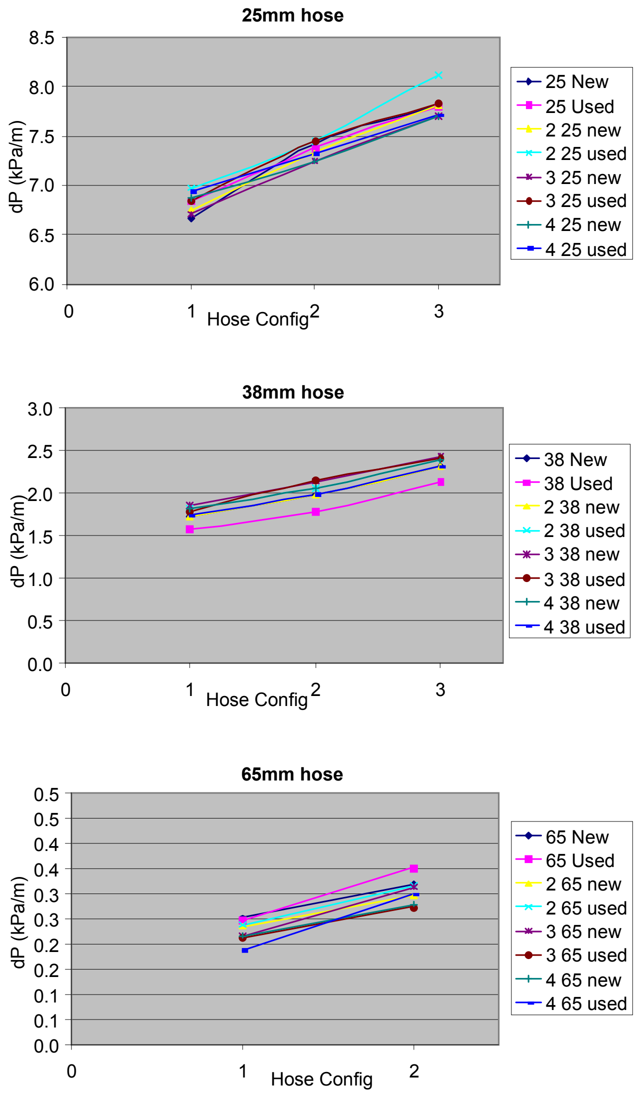

Figure 9. Pressure drop dP versus hose configuration and hose diameter; flow rate was 75.2 l/min with 25-mm hose (top), 117.3 l/min with 38-mm hose (middle), 124.4 l/min with 65-mm hose (bottom). Hose configuration: 1 – straight, 2 – with moderate bends, 3 – with severe bends. 38 used, 2 38 used, 3 38 used, etc. refer to run 1, 2, 3 with 38-mm used (old) hose, etc.

Figure 11 shows values of f in terms of hose configuration and hose diameter. It is interesting to see that while f values for smaller hoses are comparable to those of very rough rigid pipes (about 0.05), values belonging to the large hose (65-mm diameter) are much larger as well as showing a stiff rise with more bends.

Also, pressure drop was measured for the "straight" hose configuration, and compared with figures obtained according to Australian Standard AS-2792 – Fire Hose Delivery Layflat (2002) and provided by the hose manufacturer. It should, however, be noted that AS-2792 requires the hose to be under specific conditions which do not reproduce what is happening in a real-life fire-fighting situation. These test conditions require a completely straight hose under specific flow rates and pressures. On the other hand, in the "straight" configuration tested in this work, the hose still needs to curve from the back of the truck down to the ground.

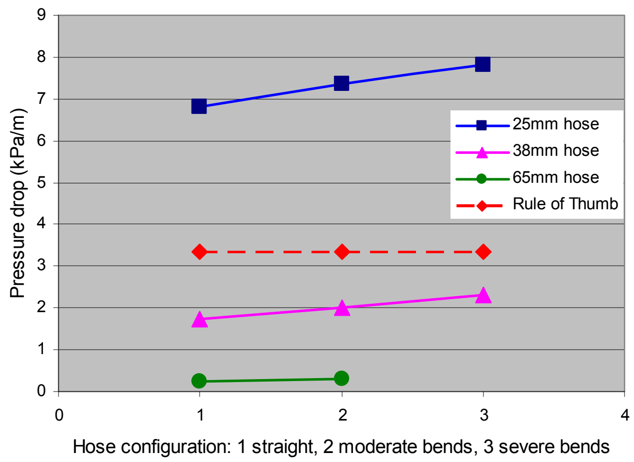

Figure 10. Average pressure drop versus hose configuration and hose diameter.

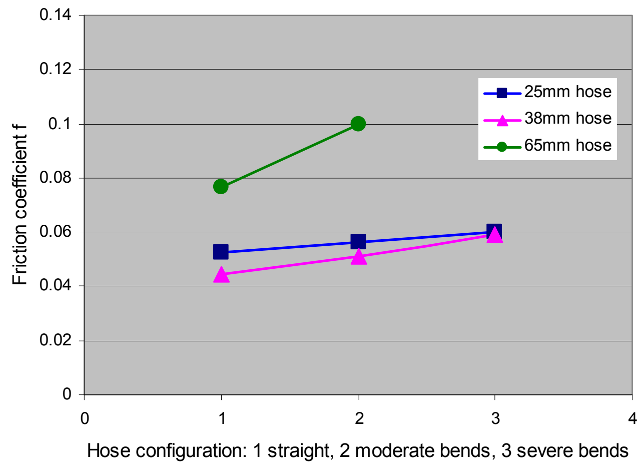

Figure 11. Friction coefficient versus hose configuration and hose diameter.

Measured results all show losses higher than the published values from tests complying with the Australian Standard AS-2792. The "straight"-hose measured values are higher than the standard as follows;

25mm hose – 1.2 kPa higher per metre (21% higher)
38mm hose – 0.1 kPa higher per metre (5% higher)
65mm hose – 0.1kPa higher per metre (27% higher)

Thus, although the standard ensures the consistency in the manufacture of all hoses and that they all perform to the same standard and quality, it is set under lab conditions and does not give a true indication of how the hoses will perform and the actual losses in real-life conditions experienced in a fire-fighting scenario.

Conclusions

This work set out to examine pressure losses in canvas hose in real-life fire-fighting scenarios and compare these to the published figures issued by the hose manufacturer complying with the Australian Standards. It was found the losses in even the most ideal situations (straight lay) were still greater than those given by the manufacturer. It was also shown that pressure loss increases significantly as the bends in the hose become more severe, especially for smaller hoses.

Hose age, which was initially thought would affect significantly the flow was found to have a negligible effect on the pressure drop.

The "rule of thumb" figure used by the NSW RFS is conservative for larger hoses, but it is an underestimation with the smaller 25-mm hose. Thus this "rule of thumb" is acceptable, but it should only be used as a general guide.

Acknowledgments

The first author wishes to thank Mr Richard Dibbs and Mr Chris Chapman of the University of Technology, Sydney, Mr Steve Hughes of the Country Fire Services, Mrs Michelle Doull, and the Glenbrook/Lapstone RFS Brigade for valuable help during the course of this work.

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