Fire Equipment Foot Valve Study Investigating Leakage Potential for Aquatic Invasive Species (AIS) Transfer

Summary

The following provides results of a study that evaluated the potential of footvalves to leak water and enable the potential transfer of invasive aquatic organisms via water handling equipment during fire events. Our results indicate that over 50% of the footvalves we tested leaked water under conditions that could be experienced in the field. Because some aquatic invasive species (AIS) can be microscopic in size, any leakage may have the potential to transfer from one location to another. Best management practices and next steps related to eliminating the potential for transfer are suggested and provided.

Introduction:

Protocols to reduce the potential for transfer of invasive aquatic organisms via water handling equipment during fire events have been discussed and investigated over the past 4 years, and best management practices have been developed. Decontamination of equipment using hot water and chemicals has also been investigated, though at times these methods can result in logistical issues such as chemical disposal and availability of hot water systems. Of particular concern has been inaccessible internal fire engine and water tender tanks, which can serve as reservoirs for Aquatic Invasive Species AIS drafted from contaminated sources. Surveys of interagency fire agencies indicated that in most instances source or stream/lake water is used to prime a pump. However, in certain instances tank water within an engine or water tender is required to prime the pump leading to the possibility of releasing potentially AIS contaminated water from a tank (through the drafting hose) into a clean water source. We investigated the ability of foot valves to reduce or eliminate the potential for AIS transfer between internal engine tanks and a pristine water source. Many of the tanked engines have internal tanks with baffles and cannot be completely emptied or decontaminated when moving from one location to another one. For this study we assumed that:

- Residual water in engines or water tenders is likely to harbor AIS.
- Most water dispersed from an engine or water tender ends up on a fire or on dry ground with little potential to enter waterways.
- Upon arriving on a new incident, engine or water tender crews might use residual tank water to prime their pump.
- Most drafting operations (~80%) use 1.5” foot valves on the suction hose. However, some large engines with 2.5”, 3”, or 4” suction lines may lack footvalves and only use a screen.(suction strainer).
- Leakage of any amount is not acceptable.

Hypothesis: Attachment of a footvalve to the end of a suction line will reduce, if not completely eliminate, the potential of residual, possibly contaminated, tank water mixing with pristine source water.

Materials and Methods:

This study was conducted at USFS San Dimas Technology and Development Center in January, 2016. Footvalves (1.5” and 2.5”) were acquired from various National Interagency Fire Caches across the U.S.

Valves were randomly selected from the cache to represent footvalve ages and conditions that are commonly seen nationwide (Photo 1). Three inch footvalves, not commonly stocked in the Fire Cache system, were obtained from manufacturers or other sources.

Footvalves were tested at two levels of pressure (3psi and 125psi) for 3 minutes and the volume of water leakage measured from each valve via weight (volume of water/cup): 1ml = 1gm. Valves were considered to have 'failed' when pressures could not be maintained and leakage exceeded ~1000 ml. Pressure levels most commonly experienced on foot valves under normal operating conditions are between 1 to 30 psi, but in certain instances for short periods of time (1-3 minutes) levels can reach 125-150psi when used under ejector operations (personal communication S.Wu, 2016).

The test apparatus consisted of a manifold capable of accommodating 5 footvalves at a time. Atmospheric pressure on a 5' vertical PVC pipe exerted pressures of 3psi on the footvalve attached to the base. A manual hand pump was used to apply 125 psi (Photo 2).

Valves tested:

- 1.5" foot valves (various manufacturers in new and/or used ready for issue): 67 total
  - 10 from Alaska
  - 29 from Redmond
  - 28 from Rocky Mountain
- 2.5" foot valves (various manufacturers in new and/or ready for issue): 30 total
  - 30 from Redmond
- 3" foot valves (various manufacturers in new and/or ready for issue): 10 total
  - Kocheck – New from 2 vendors = 6
  - Flowmatic – used = 3
  - Cascade – flapper – 1 (2 remain untested at time of this report due to manufacturer backorder)

Results

<u>Foot Valves – 1.5 inch</u>

Between 60% and 70% of the 1.5" foot valves we tested leaked, and ~10% failed completely under pressure. Tables 1 and 2 and Fig 1 summarize leakage at 3psi and 125 psi for 3 minutes.

Table 1. 1.5" Footvalve leakage @ 3psi, for 3 minutes

Volume of water leaked (ml)	No. of valves (%)	Locations[1]
0	26 (39)	3 AK, 12 RD, 11 RM
0.1 – 10	13 (19)	2 AK, 5 RD, 6 RM
11-100	15 (22)	4 AK, 7 RD, 4 RM
101-1000	8 (12)	1 AK, 4 RD, 3 RM
Complete failure[2]	5 (7)	5 RM

[1] Cache locations: AK = Alaska, RD = Redmond, OR, RM = Rocky Mountain, CO

[2] Valve leaking so much unable to attain pressure, and measure the volume of water fast enough.

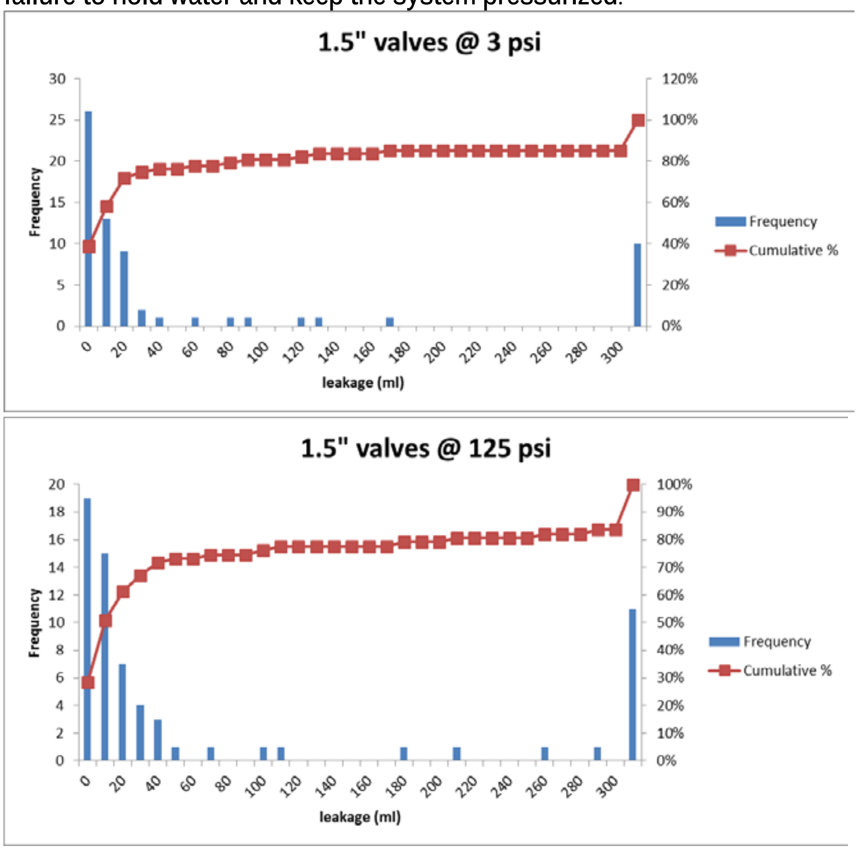
Table 2. 1.5” Footvalve leakage @ 125psi, for 3 minutes

Volume of water leaked (ml)	No. of valves (%)	Locations[1]
0	19 (28)	0 AK, 9 RD, 10 RM
0.1 – 10	15 (22)	2 AK, 5 RD, 8 RM
11-100	17 (25)	6 AK, 7 RD, 4 RM
101-1000	7 (10)	1 AK, 5 RD, 1 RM
Complete failure[2]	9 (13)	1 AK, 2 RD, 6 RM

[1] Cache locations: AK = Alaska, RD = Redmond, OR, RM = Rocky Mountain, CO

[2] Valve leaking so much unable to attain pressure, and measure the volume of water fast enough.

Fig 1. Frequency of 1.5” foot valves leakage (ml). Leakage values >1000 ml were considered complete failure to hold water and keep the system pressurized.



Foot Valves – 2.5 inch

About 35% to 40% of the 2.5” foot valves we tested leaked, but none failed completely under pressure. Leakage from the 2.5 inch footvalves was similar to that observed in the 1.5 inch valves in that some leaked very little, some at lower pressure and some at the higher pressure (Table 3; Fig. 2).

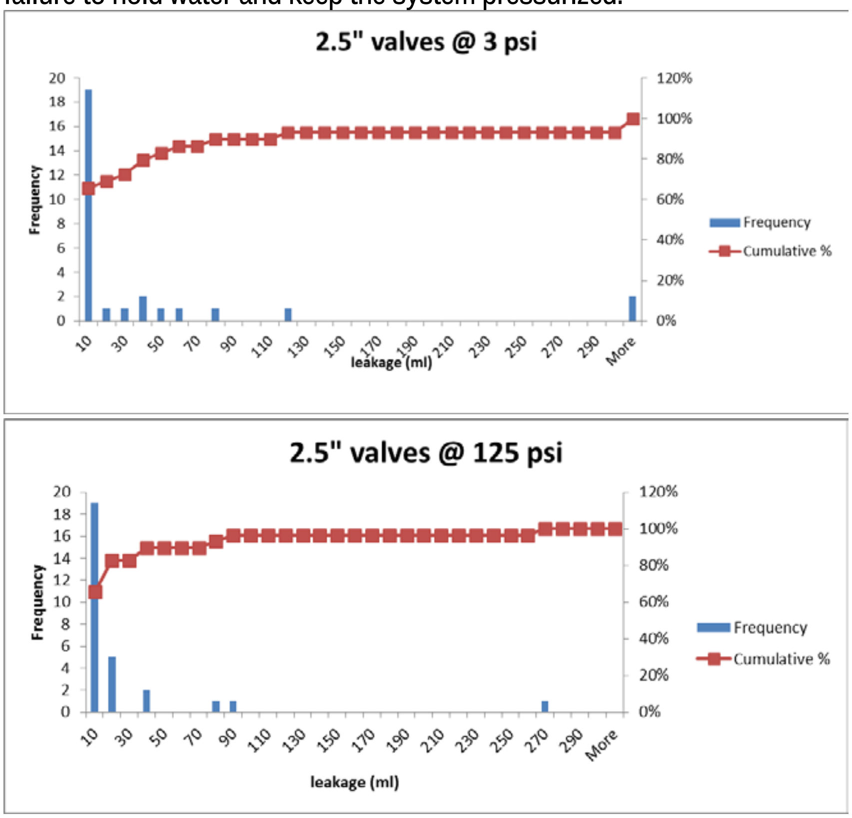
Table 3. 2.5" Footvalve leakage @ 3psi and 125 psi for 3 minutes[1]

Volume of water leaked (ml)	3psi No. of valves (%)	125psi No. of valves (%)
0	18 (58)	20 (65)
0.1 – 10	2 (6)	0
11-100	7 (23)	9 (29)
101-1000	3 (10)	1 (3)
Complete failure[2]	0	0

[1] Cache location: Redmond, OR

[2] Valve leaking so much unable to attain pressure, and measure the volume of water fast enough

Figure 1 - Frequency of 2.5" footvalves leakage (ml). Leakage valves > 1000ml were considered complete failure to hold water and keep the system pressurized.



Foot Valves – 3.0 inch

Six new 3" valves (Kocheck) were obtained from 2 different vendors. Three used valves (Flowmatic), and a new flapper valve (Cascade) were also tested. Almost all of the 3" valves leaked with a high rate of complete failure.

Table 4. 3.0" Footvalve leakage @3psi and 125 psi for 3 minutes

Volume of water leaked (ml)	3psi No. of valves (%)	125psi No. of valves (%)	Comments
0	2 (20)	2 (20)	
0.1 – 10	2 (20)	2 (20)	
11-100		3 (30)	
101-1000	1 (10)	0	
Complete failure[1]	5 (50)	3 (30)	All failures were unused Kocheck valves.

[1] Valve leaking so much unable to attain pressure, and measure the volume of water fast enough

Discussion:

Interestingly, propensity to leak was not a direct result of pressure: 18 of the 1.5" *valves leaked less at 125 psi versus 3psi (*most likely due to higher pressures against the O-rings obtaining a better seal against housing (Photo 3), *and 24 valves leaked more at 125 psi versus 3 psi. .* We were not necessarily interested in the difference between the pressures, more so investigating the potential to leak at pressures that could be experience under operating conditions.

Other observations include:

- New valves (directly from manufacturer) leaked on the initial test. However, when removed from the manifold, shaken to reseat the O-ring and retested, the valves did not leak. This was not due to incorrect installation into the testing apparatus, but considered to be in the design of the valve.
- Condition of foot valves (e.g. bent screens or noticeable wear), was not a good predictor of tendency to leak.

Causes of leakage were likely due to:

- Manufacturing defects –
  - casting of the valve housing where grooves or burrs remain and O-ring does not seat well (Photos 3, 4 and 6)
  - washer that seats the O-ring is defective, i.e., bent or misshapen
- Wear and residue –
  - O-rings in poor condition,
  - debris such as grass, sticks or rocks lodged between O-ring and housing (Photo 5)
  - poor connection between foot valve and housing (Photo 7)

Conclusion:

Between 60% and 70% of the 1.5" foot valves we tested leaked, and ~10% failed completely under pressure. Somewhat fewer 2.5" valves leaked, and none of this size failed. However, 80% of the 3" valves leaked with a high rate of complete failure. Any leakage through a footvalve of potentially contaminated tank water into a new waterbody incurs a risk of transferal of AIS, including pathogens. Although relative risk will vary with the volume of water leaked, at present there are no methods for calculating probability of AIS inoculation across the wide spectrum of possible species and environmental conditions encountered in fire incidents. Therefore any leakage of any amount is not acceptable.

However, valve leakage can be minimized through best management practices regarding footvalve installation. Because some leaks were correlated with debris, ensuring clean valve sealing surfaces is vital. Some leaks were caused by manufacturer defects (metal burrs, bent washers) and worn parts, so inspection of valves pre-incident would be effective. Some new valves leaked because O-rings were not seated properly, and shaking the housing to reset the ring eliminated leakage. This action could perhaps be added to valve BMPs.

Another approach may be to add new footvalve inspection, sampling, and test procedures to contract specifications and cache refurbishment standards to reduce the issuance of defective and dirty footvalves. Although caches represent one population of foot valves used at incidents (as a component of pump kits), many engines and water tenders are equipped with foot valves purchased outside of the cache system and therefore are not subject to Forest Service specifications and cache refurbishment standards.

Other BMP's could include educating engine crews to not use tank water to prime the pumps and providing a quick and easy method to test footvalves on site using easily acquired parts or already existing equipment on engines.

It is likely that a combination of engine/water tender crew footvalve BMPs and testing specifications would greatly reduce, though not eliminate, incidents of valve leaks and failure.

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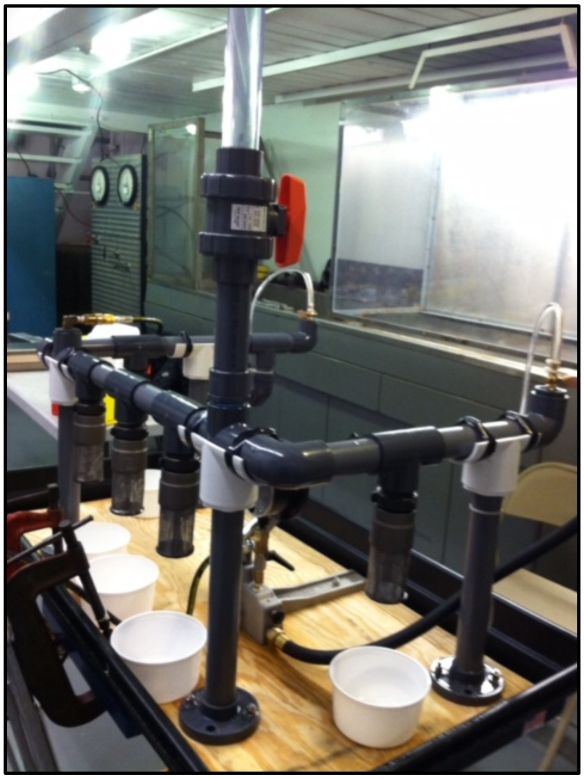
Photos of 1.5 and 2 inch Footvalves used in this study.

Testing apparatus photos: 3psi pressure obtained gravitationally via 5 ft tall PVC water column. 150 psi attained with hand pump. Water leakage was measured in cups and weighed after 3 minutes.



Footvalve defects and leakage photos: washer inside valve not completely circular (top left), o-ring frayed or internal circular washer is bent (top middle), debris embedded underneath the o-ring causing water to leak thru (top left), body casting flaw allowing water to seep between the O-ring and housing (bottom left), leakage at connection within footvalve to thread (bottom right)