Emergency Water Injection- 101

06/28/2017 updated 07/21/2017

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Figure 1 Uncontrollable Liquid

When something happens and you're faced with an uncontrollable liquid propane leak you have very few options. Depending on the size of the container and the volume of the release, a liquid propane leak can quickly create a large hazard area requiring large area evacuations, limit your ability to safely extricate trapped accident victims or identify the location of a leak.

Injecting water into a propane tank is a leak management option that most responders and suppliers have not considered. Water injection, just like all response tactics, requires special knowledge, identified tactical objectives, the proper tools and training. Water injection has been used in some areas of the country for years, but for some reason the process has not been adopted throughout the fire service and propane industry.

So now you have questions: What is it? How does it work? What type of incident would necessitate the use of Water Injection as a tactic? When should it not be used? What about the proper response equipment and training?

Propane, relationship between Temperature & Pressure

Temperature	Approximate Pressure (psi)
-10	16
0	23
10	31
20	40
30	51
40	63
50	77
60	95
70	109
80	128
90	149
100	172
110	197
120	225
130	257

Figure 2 Temp & Pressure

First, what is it? Water injection is the process of forcing water into a tank or cylinder using a water supply capable of producing more pressure than the propane tank's static pressure. If you look at Figure 2 you see that temperature dictates pressure. Under normal atmospheric temperatures most fire apparatus are more than capable of producing the pressures needed.

How does water injection work? Propane exists in a pressure vessel in one of two states, liquid and/or gas. Liquid propane weighs a little more than 4 pounds per gallon and will remain in the lowest area of the tank regardless of the tanks orientation. This area is commonly known as the wetted space while the vapor space or tank surface area above the liquid is known as the dry or non-wetted space. If a leak occurs in the vapor space, vapor is released and conversely if a leak occurs in the wetted space, liquid propane is released.

Water weighs a little more than 8 pounds per gallon (approximately twice the weight of propane) and when injected into a propane tank will sink below the liquid propane lifting and replacing it at the bottom of the tank. Once the water rises above the leak opening, the propane leak will be converted to a water leak removing the expanding hazard. As long as water is continually injected equal to the volume of the leak, the tank will continually leak water and not propane. Sounds simple, right? It is. But, injecting water into a propane tank can provide response agencies with a capability that while useful can be dangerous if done incorrectly.

What type of incident would necessitate the use of Emergency Water Injection as a tactic?

Incident #1, The tones go off and you're dispatched to a motor vehicle accident involving a bobtail. As you arrive you're faced with a passenger car wedged under the bobtail and the front passengers are trapped and need extricated. The accident has damaged the bobtail causing a liquid leak that's producing a large vapor cloud exposing the trapped victims and responders to the very real possibility of a fire.

Incident #2, You're dispatched to the County Fair and a food vender has two 100-pound cylinders mounted on the front of the trailer and one is leaking through the bottom. The visible vapor cloud is extending approximately 50 feet downwind into the midway.

We'll come back to these a little later.

What are the advantages of water injection?

Figure 3 Bobtail

Water injection can provide you with the ability to convert a liquid propane leak into a water leak stopping vapor production and providing time to mitigate the incident. Other major benefits include, better visibility to find the source of a leak, provide a safer environment for rescue and may provide containment options that allow you to move the container to a safer area. Under the right circumstances water injection can also be used to force liquid propane up so that the tank can be evacuated through other valve options. (*This tactic must only be attempted by trained and experienced personnel and only on a tank that has had its pressure reduced to a safe level due to auto refrigeration).*

Is water injection safe? Yes, when the proper protocols are followed that include identifying the tanks liquid level and pressure prior to starting operations and continuously monitoring throughout the process.

Can it be done wrong and cause problems? Absolutely, ranging from rapidly increasing tank pressure, adding stress to an already compromised tank, hydrostatic rupture and crushing victims' due to the added weight to name a few.

Will water damage the propane truck or tank? No, water will not harm any component of a tank. MC331 vessels are regularly hydrostatically tested with water to 1 ½ times their normal working pressure. When a tank is tested the water is removed and methanol is normally injected to absorb any remaining water. Once a propane tank that has had water injected to mitigate an emergency it will require service by a qualified repair shop after the incident.

When not to inject water into a propane tank.

- When a tank is in a position that would not allow the propane to be floated above the leak location prior to over filling.
- Relief operation and no liquid leak.
- *Tank volume more than 80% unless closely monitored.*
- *To off load liquid when the vessel is on its side. The weight of a tank that is half full of water is as heavy as a full tank of propane.*

Water Temperature and Special Hazards

Caution must be used when injecting water into a product that is subject to pressure changes due to temperature. Hose lines laying in the sun especially on a roadway can absorb a lot of heat and water circulating in the fire pump can be raised to boiling if not managed properly. The introduction of hot or even warm water into a propane cylinder can cause a rapid rise in tank pressure. This could result in relief valve operation or even a tank quickly reaching 100% capacity. This rise in pressure and or volume may add additional stress on an already compromised container causing a catastrophic failure. Prior to connecting the water line to the injection kit flow enough water to clear ALL warm water from the lines and the pump.

In incidents where the propane temperature is less than 32 degrees F the injected water will increase the pressure in the tank. But, as the propane in the tank cools the water, it may turn to slush and slow the leak until enough ice accumulates plugging the leak. For this to occur, water must be injected in sufficient volume to allow it to freeze prior to additional water being added that would warm the already cold water. If water is continuously injected and vapor pressure is not being flared, the propane tanks pressure will continue to rise and the warmed water may not create an ice plug. Attaching a flare capable of exceeding the tank's vapor production capability and flaring vapor only should assist with the creation of an ice plug (1-inch flare recommended).

Potential vapor cloud

Propane has an expansion ratio of 270 to 1 which means that for every gallon of propane liquid that escapes the container, it expands and creates 270 gallons of vapor. But it doesn't stop there, the 270 gallons of vapor exists at 100% concentration (too rich to burn). Propane has a flammable range between approximately 2% to 10% in air. The accompanying table expands on (pun intended) the relationship between propane's expansion ratio and just how large an ignitable vapor cloud can be. Looking at the table you see a standard 500-gallon propane tank holds 400 gallons of liquid propane when filled to 80%. If its entire contents were released the liquid would have the potential of creating more than 10,000,000 gallons of ignitable vapor. Managing an uncontrollable liquid leak with water fog to disperse vapors is most departments only option. But what if you could convert the leak to water before the release created such a large cloud? With water injection you could possibly replace the leaking propane liquid with water after only loosing "X #" of gallons? Stop and think, how would you manage an uncontrollable liquid leak if it happens today?

Tank capacity in Gallons	80% of tank volume	Approx. Gallons of Vapor at 100% Concentration	Approx. Gallons of Ignitable Vapor at the LEL (2.4%)
500	400	108,000	10,584,000
1,000	800	216,000	21,081,600
10000	8000	2,160,000	210,816,000
18,000	14,400	3,888,000	379,468,800
33,000	26,400	7,128,000	695,692,800

Where to inject water? Access into and out of propane tanks can be challenging depending on the vessels connection options. Cylinders with multi-valves may have one connection identified as liquid or fill and another for vapor out. Transports, bobtails and bulk storage tanks typically have multiple connection points, some are liquid or vapor IN, some are liquid or vapor OUT. Larger systems typically have a connection labeled as "Liquid" or "Spray Fill", it's used to fill the tank and typically has a check valve in the line (check valves allow product flow in only one direction) and provide a designated location to inject water. Or the tank may only have one valve where its filled and product removed limiting your options. Some tanks and cylinders have a separate connection known as a "Liquid Withdrawal Valve". A liquid withdrawal valve can be located on the bottom of the container or mounted on top as part of a multi-valve, or be a completely separate unit with piping to reach the bottom of the tank known as a dip tube. Tanks with a designated "Vapor" connection allow a flare to remain connected and pressure monitored during the entire water injection process. Vapor out connections normally contain an excess flow valve that allows product movement in two directions. Water can be injected through and vapor pressure removed through an excess flow valves if need be.

Figure 5 Valve Options

Figure 6 Liquid Withdrawal

Special attention must be paid to any connection that does not have an ACME or other typical hose connection. Never remove a plug with NPT (National Pipe Threads) from a tank under pressure. As you can see in Figure 5 above the third valve from the left utilizes a quick connect coupling and requires a special fitting to gain access.

Smaller tanks usually contain a single valve and are limited to only one access point for pressure readings, flaring and water injection. The tactics required for a single valve tank are a considerably different than the storage tanks discussed above.

There have been several incidents where Fire Departments were dispatched to a tank with an uncontrollable liquid leak. In the picture on the right the Fire Department was dispatched to a Bobtail with an uncontrollable liquid leak. Fortunately for them, the truck was in a desolate area and they were able to let it bleed off without incident (http://www.bemidjipioneer.com/content/road-closed-after-propane-leak).

But what happens when it occurs in town (http://www.tbo.com/central-tampa/tampa-firefighters-propane-truck-leak-under-control-18336)? Propane's vapor density is 1.5 and air is 1, any released propane vapor will sink and find the lowest areas such as basements, sewers, low areas or travel along with a moving body of water. Propane vapors moving with flowing water can travel miles.

So, let's back and look at the two incidents above:

Incident #1, motor vehicle accident involving a bobtail. As you arrived on scene you had identified a passenger car wedged under the bobtail and the front passengers were trapped and need extricated. The accident had damaged the bobtail causing a liquid leak that's producing a large vapor cloud exposing the trapped victims and responders to the very real possibility of a flash fire. You've now discovered that the truck's normal flow control options are nonfunctional and cannot be used to stop the liquid leak.

Tactical Option #1, using fog streams continuously flow water pushing air and water towards the leaking area and start the extrication process and hopefully the leaking propane does not ignite.

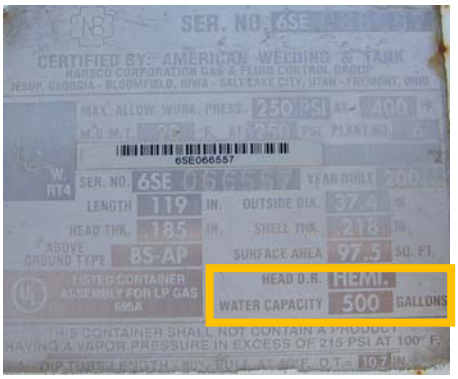
Tactical Option #2, Identify that the bobtail is a candidate for water injection (on its wheels, leaking liquid, etc.). Following the kits instructions and your training, connect your water injection kit. Inject water to the truck and flow enough water to convert the propane leak to a water leak. At this point the accumulated vapors will begin to dissipate allowing for a safer rescue. A water fog could be used to speed up the dissipation of vapors. As soon as possible connect a high-volume flare (1 inch) and start reducing the tanks internal pressure and temperature. Manage the water injection process to match the water leak and continue to flare vapor. If the amount of water being injected has sufficient weight to compress the bobtail's springs endangering the occupants, use cribbing to support the frame.

Incident #2, 100-pound tank leaking through the bottom. As you arrive on scene the food vender says he had just the tanks filled and both valves are open. You know that this type of tank normally doesn't have a lower connection option so it is believed that the tank has probably rusted through the tank shell. Any tank that's shell is compromised requires immediate actions.

Tactical Option #1 Due to the tank shell being compromised you do nothing except evacuate the area and wait. 6 hours later both tanks have emptied their contents and the vapor has dissipated.

Tactical Option #2 Due to the belief that the tank shell is compromised first arriving units decided to evacuate the immediate area. Command has decided to use water injection to convert the liquid propane leak to a water leak but not until the tanks internal pressure has been reduced. Under the protection of a fog stream (pushing and dissipating product vapors) the entry team shuts off the non-involved tank. Then using the appropriate connectors, they connect to the leaking tank and start flaring operations to reduce the internal pressure and lessen the potential of a catastrophic failure. Flaring continues at as high a rate as possible until the pressure is visibly lower (reduced flare flame due to auto-refrigeration). The tanks volume is identified using a Thermal Imaging Camera (TIC) and a frost line is visible. The tank appears to be approximately 60% full and is a candidate for water injection. The entry team connects the water injection kit, identifies the pressure using a gauge assembly and injects cool water. Within seconds the propane leak converts to a water leak and

the vapors start dissipating. Water is injected until the tank reaches 80% of its capacity (using the spit gauge) and the pressure is continually controlled and monitored. The entry team reconnects the flare and continues to flare vapor reducing the pressure further and refrigerating the tank. Using auto refrigeration, it may be possible to freeze the water and stop the leak completely. Once frozen the tank may be able to be moved to a safer location to have the remaining propane vented away. It must be noted that expanding ice has the potential of causing further damage to the cylinder.



So how much water will it take? First you need to know what the capacity of the tank is, some are identified by the weight of the propane that it holds (left chart in POUNDS), while others are identified by their water capacity sometimes marked with WC on the tag (right chart in GALLONS). Using the charts below you can get a general idea of the amount of water it takes to completely fill a tank to 80 and 100%.

In most cases it will not be necessary to water inject into smaller tanks (5-40 pound). The amount of time involved in getting on scene setting up and injecting the small volumes necessary would normally be unnecessary and unrealistic. The amount of product released from these smaller containers can usually be vented safely outdoors with little danger. But as we know never say never, there may be that one incident that requires something that is way outside of normal.

Emergency Water Injection Propane Tank Capacity Chart

	Cylinder Size in **Pounds**									
Pounds of Propane	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**100**	**200**	**420**
Water Capacity in Pounds	13	23.8	47.6	71.4	95.2	119	143	238	476	1000
Container Water Capacity in Gallons	**1.56**	**2.9**	**5.7**	**8.6**	**11.5**	**14.3**	**17.2**	**28.7**	**57.3**	**120**
Gallons @ 80%	1.25	2.32	4.56	6.88	9.20	11.44	13.76	22.96	45.84	96.00
Gallons to 100%	*0.31*	*0.58*	*1.14*	*1.72*	*2.30*	*2.86*	*3.44*	*5.74*	*11.46*	*24.00*
Gallons to 80%	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Gallons @ 70%	1.09	2.03	3.99	6.02	8.05	10.01	12.04	20.09	40.11	84.00
Gallons to 100%	*0.47*	*0.87*	*1.71*	*2.58*	*3.45*	*4.29*	*5.16*	*8.61*	*17.19*	*36.00*
Gallons to 80%	**0.16**	**0.29**	**0.57**	**0.86**	**1.15**	**1.43**	**1.72**	**2.87**	**5.73**	**12.00**
Gallons @ 60%	0.94	1.74	3.42	5.16	6.90	8.58	10.32	17.22	34.38	72.00
Gallons to 100%	*0.62*	*1.16*	*2.28*	*3.44*	*4.60*	*5.72*	*6.88*	*11.48*	*22.92*	*48.00*
Gallons to 80%	**0.31**	**0.58**	**1.14**	**1.72**	**2.30**	**2.86**	**3.44**	**5.74**	**11.46**	**24.00**
Gallons @ 50%	0.78	1.45	2.85	4.30	5.75	7.15	8.60	14.35	28.65	60.00
Gallons to 100%	*0.78*	*1.45*	*2.85*	*4.30*	*5.75*	*7.15*	*8.60*	*14.35*	*28.65*	*60.00*
Gallons to 80%	**0.47**	**0.87**	**1.71**	**2.58**	**3.45**	**4.29**	**5.16**	**8.61**	**17.19**	**36.00**
Gallons @ 40%	0.62	1.16	2.28	3.44	4.60	5.72	6.88	11.48	22.92	48.00
Gallons to 100%	*0.94*	*1.74*	*3.42*	*5.16*	*6.90*	*8.58*	*10.32*	*17.22*	*34.38*	*72.00*
Gallons to 80%	**0.62**	**1.16**	**2.28**	**3.44**	**4.60**	**5.72**	**6.88**	**11.48**	**22.92**	**48.00**
Gallons @ 30%	0.47	0.87	1.71	2.58	3.45	4.29	5.16	8.61	17.19	36.00
Gallons to 100%	*1.09*	*2.03*	*3.99*	*6.02*	*8.05*	*10.01*	*12.04*	*20.09*	*40.11*	*84.00*
Gallons to 80%	**0.78**	**1.45**	**2.85**	**4.30**	**5.75**	**7.15**	**8.60**	**14.35**	**28.65**	**60.00**
Gallons @ 20%	0.31	0.58	1.14	1.72	2.30	2.86	3.44	5.74	11.46	24.00
Gallons to 100%	*1.25*	*2.32*	*4.56*	*6.88*	*9.20*	*11.44*	*13.76*	*22.96*	*45.84*	*96.00*
Gallons to 80%	**0.94**	**1.74**	**3.42**	**5.16**	**6.90**	**8.58**	**10.32**	**17.22**	**34.38**	**72.00**
Gallons @ 10%	0.16	0.29	0.57	0.86	1.15	1.43	1.72	2.87	5.73	12.00
Gallons to 100%	*1.40*	*2.61*	*5.13*	*7.74*	*10.35*	*12.87*	*15.48*	*25.83*	*51.57*	*108.00*
Gallons to 80%	**1.09**	**2.03**	**3.99**	**6.02**	**8.05**	**10.01**	**12.04**	**20.09**	**40.11**	**84.00**
Gallons @ 5%	0.08	0.15	0.29	0.43	0.58	0.72	0.86	1.44	2.87	6.00
Gallons to 100%	*1.48*	*2.76*	*5.42*	*8.17*	*10.93*	*13.59*	*16.34*	*27.27*	*54.44*	*114.00*
Gallons to 80%	**1.17**	**2.18**	**4.28**	**6.45**	**8.63**	**10.73**	**12.90**	**21.53**	**42.98**	**90.00**

	Cylinder Size in **Gallons**							
GALLONS of Propane	**120**	**250**	**325**	**500**	**1,000**	**2,000**	**10,000**	**18,000**
Water Capacity in Pounds	996	2,075	2,698	4,150	8,300	16,600	83,000	149,400
Container Water Capacity in Gallons	**120**	**250**	**325**	**500**	**1,000**	**2,000**	**10,000**	**18,000**
Gallons @ 80%	96	200	260	400	800	1,600	8,000	14,400
Gallons to 100%	24	50	65	100	200	400	2,000	3,600
Gallons to 80%	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Gallons @ 70%	84	175	227.5	350	700	1,400	7,000	12,600
Gallons to 100%	36	75	97.5	150	300	600	3,000	5,400
Gallons to 80%	**12**	**25**	**33**	**50**	**100**	**200**	**1000**	**1800**
Gallons @ 60%	72	150	195	300	600	1,200	6,000	10,800
Gallons to 100%	48	100	130	200	400	800	4,000	7,200
Gallons to 80%	**24**	**50**	**65**	**100**	**200**	**400**	**2000**	**3600**
Gallons @ 50%	60	125	162.5	250	500	1000	5000	9000
Gallons to 100%	60	125	162.5	250	500	1,000	5,000	9,000
Gallons to 80%	**36**	**75**	**98**	**150**	**300**	**600**	**3000**	**5400**
Gallons @ 40%	48	100	130	200	400	800	4,000	7,200
Gallons to 100%	72	150	195	300	600	1,200	6,000	10,800
Gallons to 80%	**48**	**100**	**130**	**200**	**400**	**800**	**4000**	**7200**
Gallons @ 30%	36	75	97.5	150	300	600	3,000	5,400
Gallons to 100%	84	175	227.5	350	700	1,400	7,000	12,600
Gallons to 80%	**60**	**125**	**163**	**250**	**500**	**1000**	**5000**	**9000**
Gallons @ 20%	24	50	65	100	200	400	2,000	3,600
Gallons to 100%	96	200	260	400	800	1,600	8,000	14,400
Gallons to 80%	**72**	**150**	**195**	**300**	**600**	**1200**	**6000**	**10800**
Gallons @ 10%	12	25	32.5	50	100	200	1,000	1,800
Gallons to 100%	108	225	292.5	450	900	1,800	9,000	16,200
Gallons to 80%	**84**	**175**	**228**	**350**	**700**	**1400**	**7000**	**12600**
Gallons @ 5%	6	12.5	16.25	25	50	100	500	900
Gallons to 100%	114	237.5	308.75	475	950	1,900	9,500	17,100
Gallons to 80%	**90**	**188**	**244**	**375**	**750**	**1500**	**7500**	**13500**

Is your Department Ready?

Most departments and hazmat teams don't have the tools they need to perform water injection operations. Why is that? The most common answer is "we've never needed a water injection kit before". Are you sure, knowing what you know now, have there ever been incidents where water injection could have been used to lessen the hazard and shorten your on-scene time? And if water injection had been used, could you have returned the area to near normalcy sooner? Just about every HazMat team has a chlorine kit and never used it for an actual response, but they own it just in case. If you look at a commodity flow study for your jurisdiction, which do you think you have more of on site or traveling down the road, chlorine or propane? Even cities that

don’t have residential propane tanks have the potential for motor vehicle accidents involving bulk transports or alternative fuel vehicles. It might be time to add a new weapon to your arsenal.

What should a Water Injection Kit consist of? It must be easily storable and portable and allow water to be injected using industry standard connections (fire and ACME thread). The kit should have dual gauges to allow monitoring of water IN and vapor OUT pressures. Be of sufficient size to support the flow capabilities of a 1-inch flaring system. Contain a back-check valve to ensure that propane pressure cannot push back to the pumping apparatus, and contain a stress reliever hose that would allow for angled connections. And as soon as possible additional connection capabilities should be added to allow a broad range of connectivity.

Emergency Water Injection - 101

This document is ***not*** intended to teach how or when to use water injection but to provide information at the 101 level. Emergency Water Injection will provide your department with response options that are unmatched with other tactics. If your department decides to purchase and put in service a water injection kit you must read and follow all the manufacturer’s instructions and receive training from a qualified instructor prior to it's use.

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