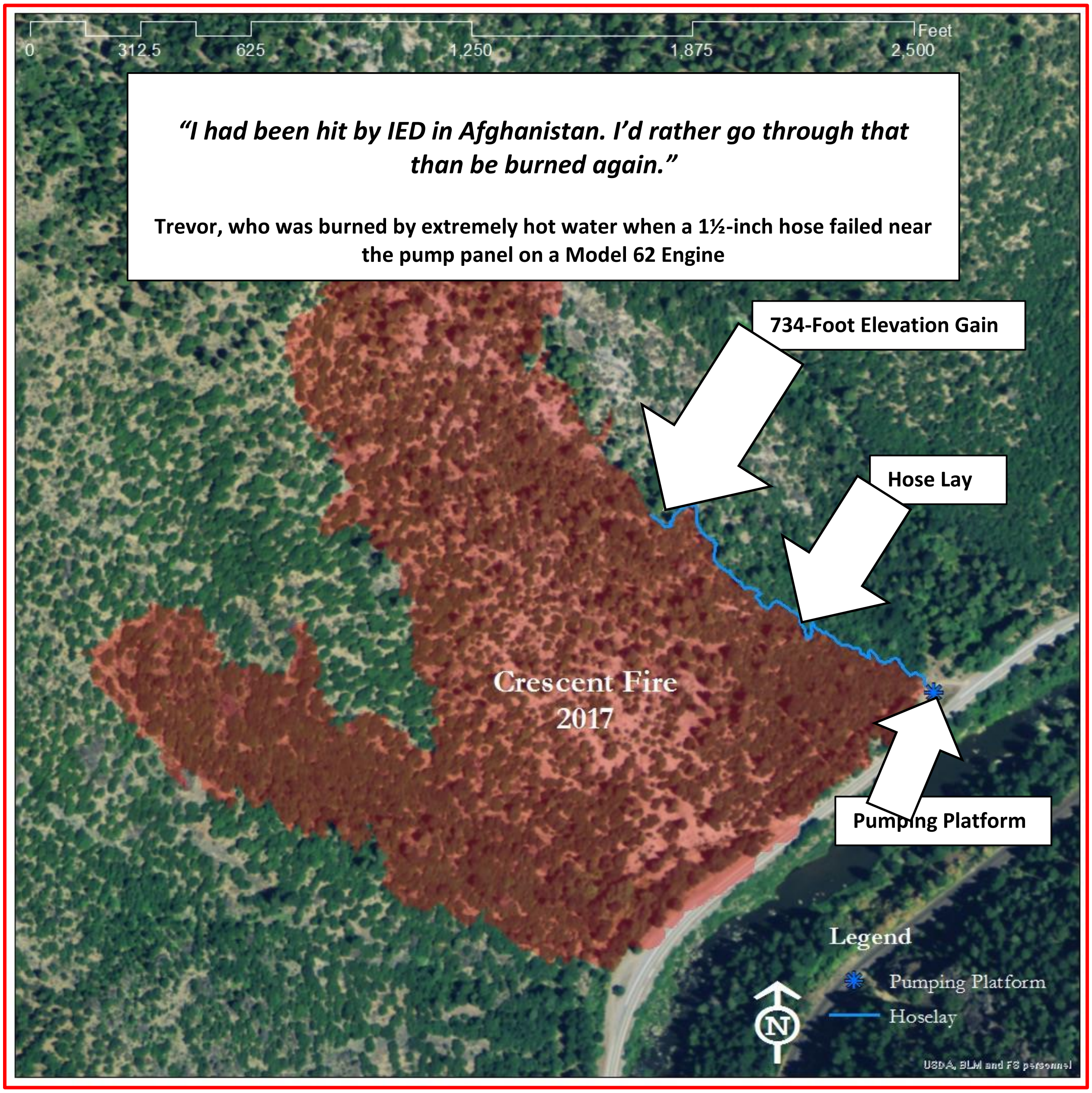
Crescent Fire Scald Injury

Facilitated Learning Analysis



Plumas National Forest

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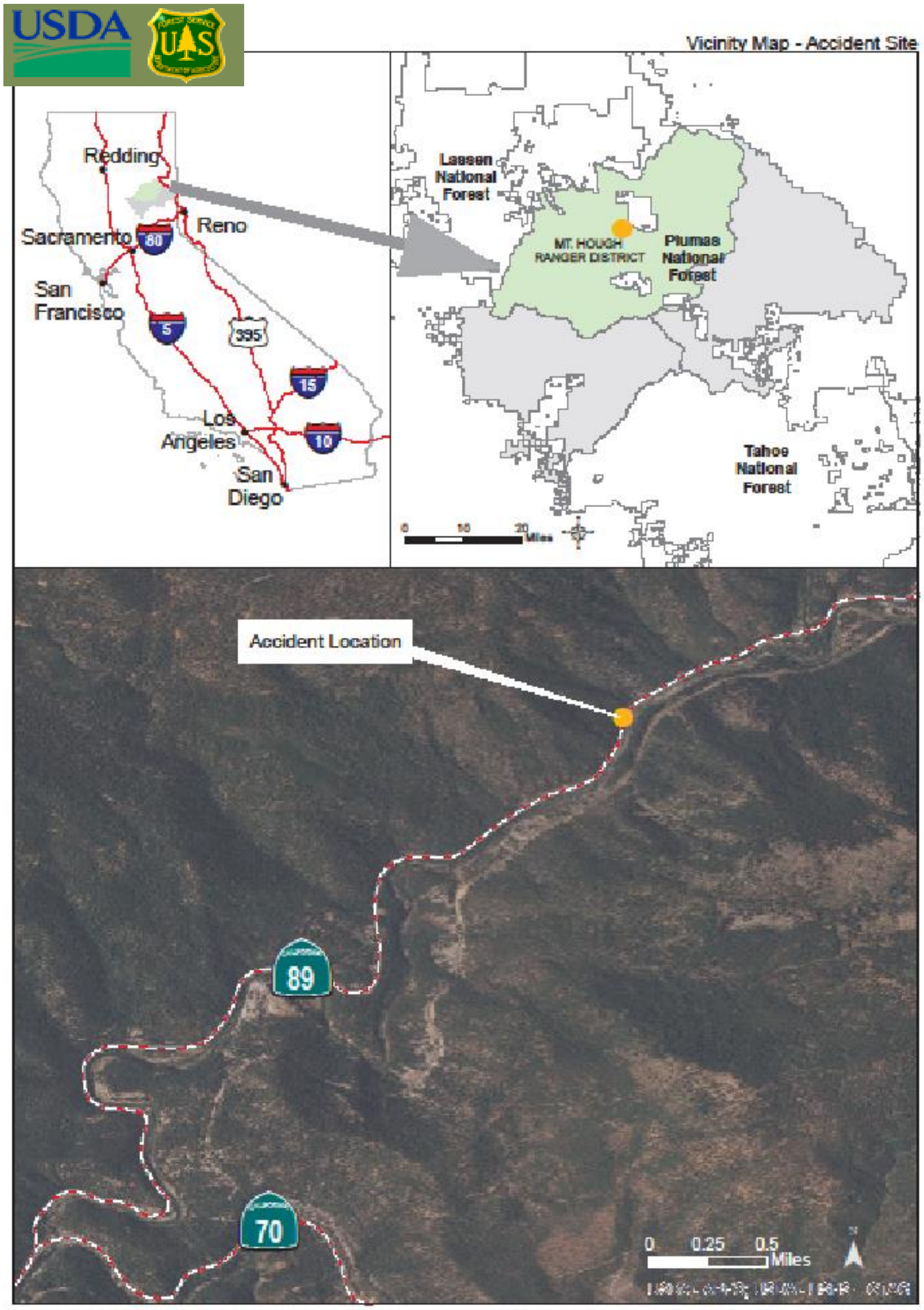
USDA
Vicinity Map - Accident Site
Redding
Reno
Sacramento
80
San Francisco
5
395
15
Los Angeles
10
San Diego
Lassen National Forest
MT. HOUGH RANGER DISTRICT
Plumas National Forest
Tahoe National Forest
0 10 20 Miles
Accident Location
89
70
0 0.25 0.5 Miles

1. Introduction

On June 30, 2017 Trevor[1] was at work at the fire station when his engine was dispatched ("immediate need") to the Plumas National Forest (PNF) as part of a Modoc National Forest (MDF) engine strike team. He had no idea that within 24 hours he would be on his way to the UC Davis Burn Center in Sacramento with major scald injuries to his torso and legs.

2. Summary

On July 1, 2017 at approximately 1200 hours, an Assistant Fire Engine Operator (AFEO) (Trevor) received burns from extremely hot water when a 1½-inch hose failed near the pump panel on a Region 5 Model 62 Type 3 fire engine. The AFEO was injured while pumping a hose lay in extremely steep terrain. The AFEO was working with another engine from the Lassen National Forest (LNF) using a parallel pumping[2] operation when the hose from his engine failed. He was struck with extremely hot water at 250+ psi, scalding his lower torso, groin, and upper legs.

3. Background

The Crescent Fire was reported to Plumas National Forest Dispatch at 1217 hours on June 30. Initial attack capabilities were exceeded and the fire grew to approximately 33 acres in size. Extended attack resources were ordered, including an engine strike team from the Modoc National Forest, identified as Strike Team 3661-C.

There were two additional fires burning in the general area and resources were spread thin.

MDF Engine 58 responded to the Crescent Fire with Trevor as the AFEO. Trevor has approximately seven years of fire experience. He served honorably in the United States Marine Corps from 2009 to 2013. He attended the U.S. Forest Service apprenticeship academy in 2014. Trevor has not had the opportunity to attend a Geographic Area Engine Academy. He has completed an Engine Operator Task Book (ENOP) and received on the job training as an AFEO.

4. The Setting

The Crescent Fire was located near Crescent Mills on the Plumas National Forest in Northern California. The weather that day was hot, in the low 80s. The terrain the fire was burning in was steep. The hose lay was approximately 1,000-1,500 feet long with an elevation gain of 734 feet. Several crews were mopping up and the operation seemed to be going well.

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[1] Fictitious names are used in this FLA to protect the identity of those involved.

[2] "Parallel Pumping" definition according to the Glossary of Wildland Fire Terminology: "*Procedure by which the flow from two fire pumps is combined into one hose line.*"

5. The Story

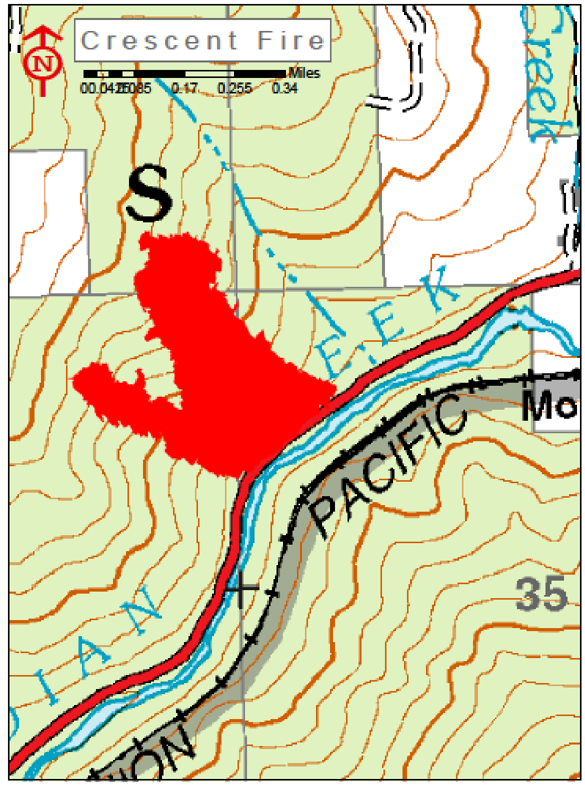
Trevor arrived at work for his regular duty day prior to 0930 on June 30. At approximately 1300, his engine crew received a request for an "immediate need" response to the Plumas National Forest to be part of a Modoc National Forest engine strike team, identified as Strike Team 3661-C.

Upon arrival at the Crescent Incident, the engine strike team was configured as a hand crew and set to work constructing hand line on the fire's right flank. The strike team worked until late in the evening when it was decided by the Division Supervisor (DIVS) to put a hose lay on the right flank of the fire, anchoring it at the bottom of the slope.

The hose lay was put in and two engines, including MDF Engine 58, pumped the hose lay until they were relieved and returned to camp to meet their 2:1 work/rest ratio requirements. The crew was bedded down by about midnight.

The next day they were briefed in the morning and MDF Engine 58 returned to the bottom of the fire's right flank to pump the hose lay again. Lassen National Forest (LNF) Engine 63 was assigned to be the second engine utilized in the parallel pumping operation.

Information gathered at the scene of the fire indicate the total hose lay was approximately 1,000 feet+, with a rise in elevation of 734 feet, and approximate head pressure of 368 psi.



Crescent Incident N120 56.887 X W40 4.277. See a Google image of the hose lay and an elevation gain graph on the next page.

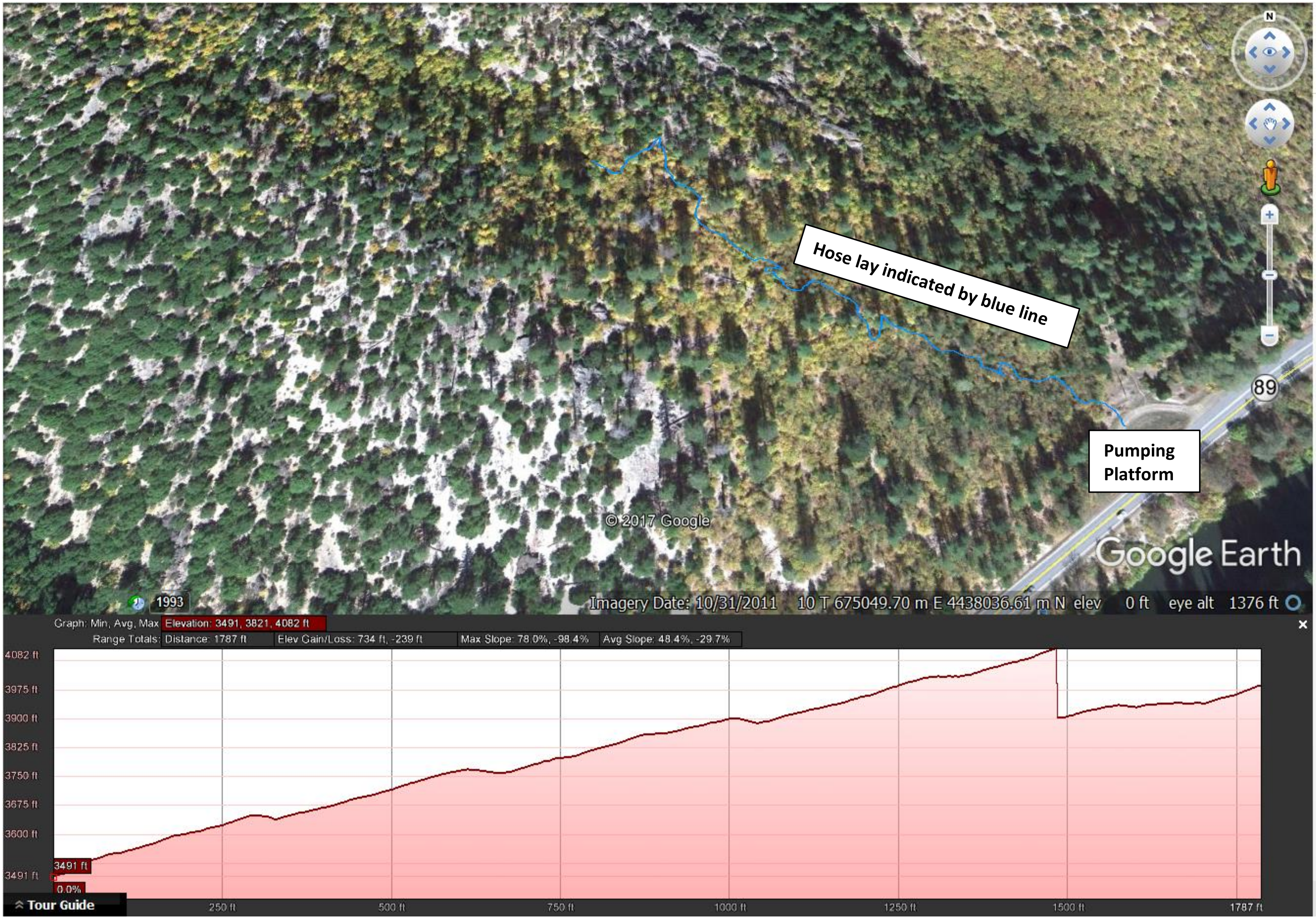
LNF Engine 63 Perspective

The crew of LNF Engine 63 came on duty at 0930 on June 30. The crew was working around their station when they received an order to respond to the Crescent Incident on the Plumas National Forest at approximately 1600 hours.

Liam was the acting Engine Captain/Fire Engine Operator (FEO) that day and was told by the Duty Officer "this is an 'immediate need' single resource order." Engine 63 is a swing/reserve engine[3]; LNF Engine 32 (the primary engine) was in the repair shop. (The use of the swing engine and alternate engine number would cause continued confusion as the incident progressed.)

LNF Engine 63 arrived at the Crescent Fire and received a briefing from the Incident Commander (IC) at approximately 1900. At 2200, Engine 63 was instructed to tie-in with the MDF strike team when it was realized Engine 63 is normally LNF Engine 32. The work that evening consisted mostly of scouting and preparation for the following shift. The engine crew went off shift at 2330. The next morning at 0700 they attended briefing and were assigned to work with MDF Engine 58, pumping the hose lay on the right flank—from the night before.

[3] Both MDF Engine 58 and LNF 63 were Model 62 swing/reserve engines. The primary engines were down for repair.


Hose lay indicated by blue line
Pumping Platform
89
© 2017 Google
Google Earth
1993
Imagery Date: 10/31/2011 10 T 675049.70 m E 4438036.61 m N elev 0 ft eye alt 1376 ft
Graph: Min, Avg, Max Elevation: 3491, 3821, 4082 ft
Range Totals: Distance: 1787 ft Elev Gain/Loss: 734 ft, -239 ft Max Slope: 78.0%, -98.4% Avg Slope: 48.4%, -29.7%
4082 ft
3975 ft
3900 ft
3825 ft
3750 ft
3675 ft
3600 ft
3491 ft
0.0%
Tour Guide
250 ft
500 ft
750 ft
1000 ft
1250 ft
1500 ft
1787 ft

Both Trevor and Liam felt uncomfortable with this pumping operation. However, neither of them voiced this concern to each other—or to anyone else.

"It is not what I would have done."

Liam, Acting Engine Captain/Fire Engine Operator, LNF Engine 63 (referring to the type of pumping operation that was being used).

The Next Day – July 1, 2017

Trevor knew Liam, both of them having worked together on previous fire assignments.

Liam and Trevor connected their engines' short sections of 1½-inch hose (approximately 20 feet) to their overboard discharge valves (#3) and to a gated wye set up as a Siamese[4]—utilizing the same hose lay configuration as the night before.

The previous night, Engine 58 and another Modoc National Forest engine from the strike team were used to pump the hose lay. The thought behind this operation was to use two Model 62 engines set up as a parallel pumping platform in order to overcome the steep terrain and head pressure.

A Lassen National Forest water tender was supplying water in support of this operation.

Both engines were set up and pumping at nearly the same pressure(s) all morning. Each engine was pumping at about 250 psi. The engines were alternately overpowering each other.[5] They noticed on the foam proportioning system's water flow meter that one engine would flow about 30 gallons per minute (gpm) for a short time period, while the other engine flowed 0 gpm. Then the other engine would flow about 30 gpm for a short time, alternating back and forth between the two pumps. Liam stated: "This was the exact same thing that was happening the night before".

Both Trevor and Liam felt uncomfortable with the parallel pumping operation. Neither of them voiced this concern to each other or anyone else. Trevor felt it may have been better to move one engine to the top of the fire and pump the hose lay from a two-track road in that location. Liam felt uncomfortable attempting to keep both engines pumping at the same pressure. Liam thought a "series" pumping operation might have worked better.

Around 1130, they received a radio call from one of the crews working the hose lay, notifying the engines that firefighters did not have water pressure to the end of the hose lay. Liam responded that they would bump the pressure up to about 275 psi. Both engines were now pumping at 270-290 psi.

[4] From Wikipedia: *"A 'Siamese connection' in fire protection engineering is a hose fitting that allows two or more fire hoses to be connected to a single hose lay at the same general location."*

[5] When this happens the pump flowing water is the lead and the other is the follower. The lead engine is the only one flowing water and the follower's water flow is essentially capped at the first check valve in the plumbing.

"When the hose burst it got me in the groin. I spun around. I ran to the shade. I was not sure if that was the water pressure stinging me or what. Then I ripped my shirt off and I was all red. I ran to the engine and ripped off boots and pants. That's when I noticed my skin falling off."

Trevor, Assistant Fire Engine Operator
MDF Engine 58

They pumped at this pressure for a short period of time, less than 30 minutes. Both Trevor and Liam then observe a pressure leak in the short discharge hose coming from Engine 58 somewhere between the coupling at the discharge valve and the ground.

Trevor then moves to the engine and reaches for the throttle to shut the engine down. He is directly in alignment with the overboard discharge valve (#3). While reaching for the throttle, the hose blows off the coupling, spraying Trevor in the groin with extremely hot water at about 275 psi.

As the hose fails, Liam braces himself and prepares to get hit with the hose and/or water. Liam gets sprayed with a small amount of water and realizes it is very hot. He cannot see Trevor, who has run from the engine into the shade and started removing his water-soaked clothing.

Trevor remembers: "When the hose burst it got me in the groin. I spun around. I ran to the shade. I was not sure if that was the water pressure stinging me or what. Then I ripped my shirt off and I was all red. I ran to engine and ripped off boots and pants. That's when I noticed my skin falling off."

Liam sees this and calls for the Emergency Medical Technician (EMT) who is staffing the Forest Service water tender, supplying water to both engines. The EMT quickly comes to Trevor's aid and starts to treat his injuries. Notification of the injury is made to the Division Supervisor. Emergency Medical Services (EMS) is activated, including a ground ambulance (Medic-7) from Greenville and a Medevac Helicopter (PHI Air Medical Med-45) is ordered through PNF Dispatch.

When the ambulance arrives, Trevor runs to meet them. He is taken to the Taylorsville golf course landing zone to be transported by helicopter. The IC Trainee requests Dispatch to instruct the flight crew to transport Trevor to the nearest burn center in accordance with the Interagency Standards for Fire and Aviation Operations (Redbook) recommendations. Trevor is transported by helicopter to the UC Davis Burn Center in Sacramento, arriving at 1342.

After the accident it was discovered that a gated wye, 300 feet up the hill, was closed halfway. It is unknown how this occurred, accidentally or intentionally, of if it had any effect on the pumping operation.

Medical Response

In general, firefighters were able to follow their training with regards to the medical incident. Trevor received immediate aid from the EMT that was staffing the water tender. He was receiving medical care from the responding ambulance within approximately one half hour of receiving his injuries. Trevor arrived at the burn center by helicopter within two hours from when his medical incident first occurred.

6. The Timeline

Time	Description of Events	Source
7/30 0930	Engines come on duty and start regular work shift at home fire stations.	Trevor
~1300	MDF Swing Engine 58 dispatched Immediate Need to the PNF Crescent Incident as part of Strike Team 3661-C.	Trevor
1502	LNF Water Tender-1 Responding to Crescent Incident.	Disp
~1600	LNF Engine 63 dispatched Immediate Need to the PNF Crescent Incident.	Liam
~1700	MDF Engine 58 Arrives at Crescent Incident.	Trevor
~1730	Strike Team formed into hand crew.	Trevor
~1900	LNF Engine 63 arrives at Crescent Incident.	Liam
1949	Strike Team 3661-C on scene.	Disp
2200	LNF Engine 63 advised they are part of Modoc Strike Team.	Liam
~2330	The Strike Team beds down for the night at the Greenville Work Center.	Liam
8/1 0600	Breakfast.	Liam
0700	Attend morning briefing.	Liam
~0800	Back to fire to pump same hose lay as day before on the fire's right flank.	Trevor
~1130	Crew calls and reports no pressure in hose lay at the top.	Liam
~ 1132	Pressure is increased to 270-290 psi.	Liam
~1137	A pressure leak is noticed in the short hose coming from Engine 58.	Trevor
~1140	Trevor reaches for the throttle to shut down the engine when the hose blows off the #3 valve and he is burned by extremely hot water coming from the pump of MDF Engine 58.	Trevor
~1145	Requested EMT to check on Trevor and treat his burns.	Liam
~1148	Informed DIVS about accident.	Liam
1150	Ground ambulance is ordered by DIVS.	Disp
1152	Medevac Helicopter (PHI Air Medical Med-45) ordered by DIVS.	Disp
1211	Ground Ambulance on scene. Med-45 ETA 13 minutes.	Disp
1241	Request made to fly patient to UC Davis Burn Center in Sacramento, Calif.	IC-T
~1230	Med-45 lands at Taylorsville golf course. Patient is transferred from ground ambulance to medevac helicopter.	Disp
1300	Med-45 enroute to UC Davis Burn Center.	IC-T
1342	Trevor arrives at UC Davis Burn Center aboard Med-45.	Disp

The ~ mark in the "Time" column indicates an estimated time.

7. Lessons Learned

- Comments from Trevor: "My biggest thing now is slowing down; don't be in such a rush. If the fire is not doing anything, maybe we can slow down and consider tactics. What can we do on the next one? But then, is it worth it? It's just snags and poison oak. We need to reevaluate the whole situation. I think there are some things we could have done on that. Maybe I need to voice my opinion on how we could do it differently."
- There is a time and place to use short sections of 1½ inch hose. Make sure they are tested annually.
- When pumping a complex hose lay, always feel the brass near the pump to determine if the pump is heating up.
- If you see a pressure leak in a high-pressure hose, use caution!
- Explore the possibilities of having pump temperature gages installed on new engine buildups.
- Research the size of the #17 valve return cooling line; consider enlarging this return line.
- Research the remote engine kill switch.

8. FLA Team Observations

The Pumping Operation

- Typically parallel pumping operations are used to increase the volume of water supplied, not pressure. Because of the difficulty in keeping the two pumps at exactly the same pressure, this configuration is ineffective when compared to a series pump configuration in increasing nozzle pressure.
- Typically U.S. Forest Service engines are not equipped with the proper appliances and proper hose diameters to effectively use parallel pumping operations. Also, the friction loss is usually increased when using parallel pumping. The training that Forest Service pump operators receive for parallel pumping is for use with smaller portable pumps and should be considered an unnecessary pumping operation for Type 3 engines.
- There are different testing requirements for "attack" fire hose and "supply" fire hose. If short sections of hose that are intended for use as supply hose are used for fire hose, this hose may not have been tested for the higher pressures used for attack hose.
- Caution should be used any time firefighters, especially engine operators, are working near high-pressure hose lines.
- The size of the current return cooling line is of sufficient size and allows adequate flow for cooling of the installed pump. The return line is also the pump manufacturer's recommended line size for the installed pump.
- It cannot be understated the importance of having good emergency medical response plans and practicing implementing them through live exercise, and including cooperators. Consider worst-case scenarios and think about what you would do in various situation

Questions

- How do you determine if your engine is flowing water during complex hose lay operations?
- Do you know how to determine if your pump is overheated?
- Have you ever overheated the pump on your engine?
- How did you respond to the overheated pump?
- Are you willing to speak up when you feel there is a better way to achieve an objective?

9. FLA Team Members

Peter Tolosano, Team Leader, Retired Risk Management Officer, Pacific Southwest Region

Karen Juska, Safety Officer, Plumas National Forest

Zac Cogle, Engine Captain, Plumas National Forest

Robert Manwaring, Equipment Specialist, San Dimas Technology and Development Center

Kathy Powers, Union Representative, Plumas National Forest

10. Appendix – Fire Engine and Equipment Analysis

At the request of the Crescent Fire Scald Injury Facilitated Learning Analysis (FLA) Team, the U.S. Forest Service National Technology and Development Program (NTDP) conducted inspection, evaluation, and analysis of the fire engine and related water handling equipment associated with the incident. A Fire Equipment Specialist from the NTDP San Dimas Center was assigned to the FLA Team to perform necessary equipment inspections, analysis and performance tests.

1. INTRODUCTION

Fire Engine Inspection
This report compiles information from accident site visits, examination of photographs of the site taken by FLA team members and U.S. Forest Service law enforcement, and inspection of the recovered fire hose and the fire engine involved in the incident.

Initial equipment inspection was conducted in Alturas, Calif., at a Modoc National Forest fleet equipment facility. Fire pump inspection was conducted at a local repair shop located in Alturas. Both of the preceding inspections were conducted by a Fire Equipment Specialist from the U.S. Forest Service's National Technology and Development Program (NTDP).

The fire engine and associated water handling equipment was then transported to the NTDP San Dimas Center for more comprehensive evaluation and analysis. NTDP staff tested the fire engine for water flow rate and water temperature at various pump pressures through the #17 pump cooler bypass line to determine the source of the scalding water.

Testing was accomplished using low volume flow meters, measured volume containers, stopwatch, and contact thermocouple temperature measuring devices. Water flow is expressed in gallons per minute (gpm). The pump pressure is expressed in pounds per square inch gauge (psig). The water temperature is expressed in degrees Fahrenheit (such as 60° Fahrenheit). Fire hose, coupling and line sizes are expressed in inches and fractional inches (such as 1½ inches). The fire hose, coupling and expansion ring was only subject to visual inspection.

Fire Engine and Pump
CA-Modoc National Forest (MDF) Engine 58, door number 6730, is a Region 5 Model 62 Type 3 fire engine. The fire package was built by Boise Mobile Equipment and mounted to a Navistar International 4800 cab and chassis. Engine 58 was delivered to the Modoc National Forest on January 17, 2002. It was put into service on February 25, 2002.

The fire pump installed in the buildup is a Darley JMP 500, serial #19636. The Darley pump is a dual mode, pressure and volume pump, rated to 500 gpm.

2. THE ACCIDENT SITE

The Crescent Fire was located on the Plumas National Forest in Northern California. The fire engines involved were located in a horseshoe-shaped pullout with a fairly level earthen platform adjacent to a paved two-lane road. Terrain was very steep along the fire's flank where the engines were supplying water for a hose lay.

3. DISCUSSION

Pumping Operation

From information collected during various interviews, it was determined the pumping operation used during the accident was parallel pumping. Arrangement of the hose and fittings required for the operation had been in place from the previous shift.

Two fire engines from an organized strike team were put into place to pump the hose lay. The engines were placed pump panel to pump panel, approximately 15 feet apart. Engine operators from CA-Modoc National Forest (MDF) Engine 58 and CA-Lassen National Forest (LNF) Engine 63 hooked up their respective engines to the hose lay using short filler hoses from their engines to supply water to firefighters performing mop-up along the fire's flank.

Arrangement of the short hoses connected to the #3 overboard discharge from the engines were plumbed into a gated wye valve. The gated wye valve was configured in reverse to allow the water supplied for both engines to combine into a single hose. Both of the engines were pumping water from their tanks and were being supplied water from a single U.S. Forest Service water tender.

The pump engine operators had been pumping at approximately 250 psig all morning, manually matching pump pressures. At some point during the operation, the pump operators received a radio call stating that water wasn't getting to the end of the hose lay. Both pump operators responded by increasing pump pressure from 250 psig to around 290 psig. Throughout the entire pumping operation, both pump operators had noticed only one engine flowing water at any given time, swapping water flow back and forth between engines.

Shortly after increasing pump pressure, a pinhole leak was discovered in the short discharge line from CA-MDF Engine 58's #3 overboard discharge. Engine 58's operator began to throttle down his pump and leaned across the discharge line to reach the throttle control. While in the process of throttling down the engine, the discharge line failed and the hose separated from the coupling. This resulted in extremely hot water discharged from the pump.

Hot water contacted the operator's lower torso and upper portions of both legs, ultimately causing second degree burns to the operator. The operator of CA-LNF Engine 63 saw the failure and turned to brace for an impact from the hose and water. After being contacted with water, the operator of CA-LNF Engine 63 turned back to look at Engine 58. Noticing the operator from Engine 58 was not near the operator's panel, the Engine 63 operator quickly throttled down both engines and shut down the hose lay.

Initial Equipment Inspection

Initial inspection of the CA-MDF Engine 58 took place in Alturas, Calif., on July, 10 2017. The purpose of this inspection was to determine if there were any obvious mechanical indicators or damage which may have contributed to the scalding injury.

Engine 58 was found to be in working order with the pump, plumbing and valves all in working condition. The pump bypass valve (#17) was in the open position and water was returning to the tank with the pump throttled to 150 psig. The water flow rate through the bypass line was not recorded due to lack of access to required measurement equipment.

The engine was taken to a local service shop where the pump was removed from the engine. The pump was then disassembled to determine any indication of damage due to "cavitation." ("Cavitation" is defined as a condition when bubbles form in the water due to low pressure and high temperature conditions. When the bubbles implode due to changes in pressure, shock waves are created that can damage pump components and cause pump failure.) However, upon inspection, the internal pump components were observed to be in excellent condition with no indication of damage. The pump was then reassembled and reinstalled onto Engine 58 and transported to the National Technology and Development Program, San Dimas Center for further inspection and intensive testing.

Equipment Testing and Findings

Equipment testing began on August 1, 2017 at the National Technology and Development Program, San Dimas Center for the purpose of understanding the causes for the pump water heating to the point of causing scalding injuries. Preliminary testing was performed to provide baseline performance in Engine 58's initial state.

Because the purpose of the pump bypass line is to cool water temperatures in low flow operations by keeping some water flowing through the pump, the NTDP staff began by specifically looking at the pump bypass line and valve. These tests involved running the pump at various pressures with the tank to pump valve (#1) open, pump bypass valve (#17) open, and all other valves closed (dead heading). Test equipment included flow meters and thermometers.

The overall goal of the testing was to provide reasonable recommendations to the FLA Team once preliminary testing was completed and potential performance issues had been remedied.

<u>August 1 Testing</u>

On August 1, the NTDP staff ran Engine 58 through a range of pump pressures from idle to 400 psig for the purpose of checking the quantity of water flow through the pump bypass line. During Test #1, water flow returning to the tank decreased as the test progressed. The pump bypass valve was then cycled from open-close-open, and the water flow returned to the original flow at the beginning of the test. The pump pressure was held to 400 psig and allowed to run for approximately 10 minutes. Water temperature returning through the pump bypass line measured 163° Fahrenheit. The pump was returned to idle and shut down.

In Test #2, Engine 58's pump was once again tested through a range of pressures, from idle to 400 psig. The water flow through the pump bypass line during Test #2 was reduced to almost a dribble. The pump was returned to idle from 400 psig immediately upon noting the reduced water flow through the bypass line. The water temperature was taken at the pump bypass return point at the top of the tank. Water temperature reached 114° Fahrenheit while pumping at 100 psig.

NTDP staff posited that there was either something with the valve or an obstruction in the bypass line that was causing intermittent fluctuations of water flow. The pump bypass valve was subsequently cycled while in pressurized operations, leading to an increased water flow through the bypass line. An inline 5 gpm flow meter was inserted on the pump bypass line to determine flow.

For Test #3, the pump was throttled to 400 psig. No water flowed through the bypass. After cycling the pump bypass valve, water again flowed through the bypass line. The flow meter showed 2.5 gpm at 400 psig and 2.5 gpm at 300 psig. During the test evolution, NTDP staff noticed a water leak in one of the high pressure lines in the foam system. Testing was discontinued until the high pressure line was repaired.

<u>August 2-3 Testing</u>

During August 2-3, after replacing the high pressure line in the foam system, testing resumed. Data from tests #4, #5, #6, #7, #8, and #9 are tabulated on the next page.

Test #4

PSIG	GPM	Temperature
100	1.25	82° f
200	2	101° f
300	2.5	125° f
400	2.8	137° f

Test #5

PSIG	GPM	Temperature
100	1.6	None taken
200	2.5	None taken
300	3.0	None taken
400	3.6	None taken
400	3.2	131° f
250	2.6	133° f
300	2.7	125° f

Test #6: 300 psig for 20 minutes

PSIG	GPM	Temperature
300 (6 min)	3.0	121° f
300 (10 min)	3.0	123° f
300 (15 min)	3.0	122° f
300 (20 min)	3.0	122° f

Test #7: 300 and 400 psig, pump operated until temperature stabilizes

PSIG	GPM	Temperature
300	1.3	None taken
300	1.2	116° f
300	1.2	121° f
300	1.2	138° f
300	1.2	143° f
300	1.4	145° f
300	1.4	146° f
400	1.5	148° f
400	1.5	153° f
400	1.5	156° f
400	1.5	160° f
400	1.5	162° f

Test #8

PSIG	GPM	Temperature
100	0.37	82° f
300	0.76	100° f
300	0.7	122° f
300	0.7	136° f

300	**0.7**	**148° f**
Pump bypass valve (#17) is cycled twice.		
300	**2.5**	**152° f**
300	**2.6**	**134° f**
300	**2.6**	**125° f**
300	**2.6**	**123° f**
400	**3.0**	**124° f**
400	**3.0**	**126° f**
400	**3.1**	**133° f**
400	**3.1**	**128° f**
400	**3.0**	**128° f**

Test #9

PSIG	GPM	Temperature
300	**0.95**	**114° f**
400	**0.98**	**135° f**

After performing Test #9, the pump bypass valve was removed for inspection. No defects or obstructions were found within the valve body or control mechanism. This strongly suggested that something in the bypass line was the cause of the intermittent flow.

NTDP traced the bypass line from the tank back to the pressure side of the pump. The line was located on the pressure side of the plumbing adjacent to the pump and was disconnected. Pressurized air was introduced to the bypass line from the line's connection point at the operator's panel to confirm that the correct line was disconnected. All of the water was forced out of the line. The same process was done for the bypass line from the operator's panel to the top of the engine. The lines were then reconnected and testing resumed.

August 3-4 Testing

During August 3-4, using the same consistent testing method in tests #10-15, NTDP demonstrated that the clearing of the bypass line removed an obstruction that impacted the amount of cooling that could occur in pump operations.

Test #10

PSIG	GPM	Temperature
100	**3.2**	**100° f**
200	**4.8**	**98° f**
300	**6.3**	**102° f**
400	**7.0**	**106° f**

Test #10 showed the highest flow rates from any of the tests conducted to this point. The temperatures recorded at the bypass line's return point were stable and did not reach the high temperatures seen in previous tests.

While there was no debris or obstruction captured during the introduction of pressurized air to the bypass line, it was concluded that an obstruction was cleared during the procedure. Test #11 validated the resulting measurements of water flow and temperature.

Test #11

PSIG	GPM	Temperature
100	2.8	94° f
200	4.6	95° f
300	5.3	102° f
400	6.4	108° f
400	6.3	110° f

Test #12

PSIG	GPM	Temperature
100	2.8	78° f
200	4.0	83° f
300	5.4	90° f
400	6.7	100° f
300 (1 min)	5.9	94° f
300 (2 min)	5.3	99° f
300 (5 min)	5.4	99° f
300 (10 min)	5.3	99° f
300 (15 min)	5.9	98° f

Test #12 did not show the high temperatures and low flows experienced in earlier testing. The flow rated displayed were stable throughout the test and no extreme changes were noted as in previous tests.

Temperatures tabulated in tests #13-15 are indicative of the water temperatures after temperature stabilization. No significant changes in water flow were observed through the bypass line, thereby allowing for the sufficient flow of water through the pump during low water flow operations.

Test #13

PSIG	GPM	Temperature
100	2.5	69° f
200	3.8	76° f
300	4.8	95° f
400	5.7	105° f

Test #14

PSIG	GPM	Temperature
100	2.5	Non taken
200	3.6	Non taken
300	4.9	96° f
400	6.5	106° f

Test #15

PSIG	GPM	Temperature
100	2.6	93° f
200	3.8	93° f
300	5.3	98° f
400	6.4	106° f

4. RECOMMENDATIONS

Findings

An obstruction in the pump bypass line on the Region 5 Type 3 Model 62 fire engine did not allow for adequate water flow through the line during the pumping operations. This condition led to the excessive heating of water sufficient to sustain burns. This problem with the pump bypass line was identified during the Facilitated Learning Analysis equipment evaluation.

Required Action

1. Check the #17 pump bypass valve for obstruction. Inspect water flow through the pump bypass line by engaging the pump, opening the tank to pump valve (#1), closing the pump to tank valve (#2), opening the pump bypass valve (#17), and closing all other valves. Run the pump up to 400 psig and visually check the water flow at the line's return point at the top of the tank. The return point should be located near the tank tower on top of the engine. Water flow at the return point should be a fairly strong stream of approximately 6 gpm.

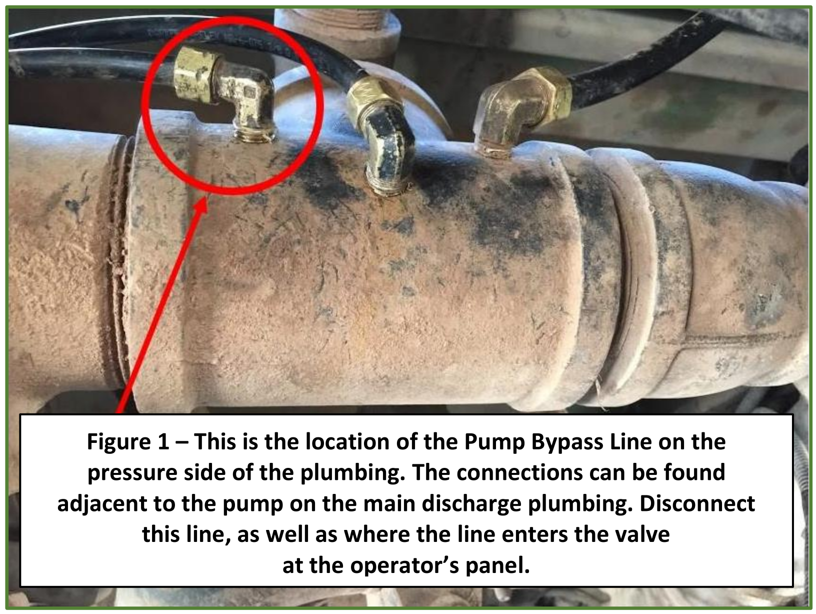


Figure 1 – This is the location of the Pump Bypass Line on the pressure side of the plumbing. The connections can be found adjacent to the pump on the main discharge plumbing. Disconnect this line, as well as where the line enters the valve at the operator's panel.

Figure 2 – The location where the Pump Bypass Line enters and exits the valve is behind the control knob on the operator's panel. Disconnect both the entering line and the exiting line. Once the Pump Bypass Line has been disconnected in the described three locations, apply pressurized air from a compressor. The pressurized air should be applied to both the line of the disconnected lines.

2. Disconnect the pump bypass line from the pressure side of the plumbing (see Figure 1) and the valve at the operator's panel (see Figure 2). Once the line is disconnected, clear the line with pressurized air using an air compressor (shop pressure between 90 – 100 psi).

   The line from the valve at the operator's panel to the top of the tank should also be cleared with pressurized air. Reconnect the line to the pressure side of the plumbing and valve at the operator's panel, as well as the line from the valve to the top of the tank. This should clear any possible obstructions in the pump bypass line.

   This required action should take approximately 20 minutes to complete.

   Clearing of the pump bypass line can be accomplished by Fire and Aviation Management employees at the local level. If after completing the required action, the water flow through the pump bypass line still appears obstructed, the engine should be taken out of service until repairs are made to restore sufficient water flow.

5. SUMMARY

The pump bypass line is used during pumping operations to allow adequate water to flow through the pump during periods where firefighters at the nozzle may be using little to no water. Allowing sufficient water to flow through the pump cools the water enough to avoid cavitation. (Cavitation can occur in pumps when water temperatures rise too high and bubbles form in the water, damaging pump components upon the implosion of bubbles.)

As a result of this July 2017 scalding water injury, the U.S. Forest Service National Technology and Development Program (NTDP) inspected the pump bypass lines on several Region 5 Model 62 fire engines. The inspection determined that the bypass line can be partially or fully obstructed. The obstruction reduces the amount of water able to flow through the line, resulting in high water temperatures in the pump and portions of the plumbing.

NTDP developed short term inspection and corrective actions as delineated in the "Required Action" section. Longer term, permanent solutions will follow. Thus far, the known affected units are fire engines built to the Region 5 specification prior to 2009. ***However, all engines and water tenders should inspect the water flow through the pump bypass line.***

Operation of the Pump Bypass
The pump bypass valve (#17) should always be in the open position, unless pumping "source to fire" with a full tank. In the case of pumping "source to fire" with a full tank, water flow through the pump bypass line can overflow the tank.

Follow-Up Actions
A U.S. Forest Service National Technology and Development Fire Equipment Specialist will work with Washington Office Fleet Safety to ensure the implementation of the recommended solutions. In addition, Regional Fleet Managers will work with Forest Fleet Managers for local implementation.

For Additional Information
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