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Development of a recommended standard for off-highway, ground-based water delivery systems for Alberta

Abstract

The Forest Engineering Research Institute of Canada (FERIC) surveyed off-highway, ground-based water delivery systems working in Alberta wildland fire operations to develop a recommended standard for these types of systems. This report contains information useful in the design and operation of mobile water delivery equipment in support of Alberta fire operations.

Keywords

Water delivery systems, Tanks, Fire management, Fire suppression, Wildfires, Safety, Alberta.

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Introduction

The primary role of off-highway, ground-based water delivery systems is to support wildfire operations during mop-up and control conditions that are common when the head fire intensity is less than 500 kW/m.[1] The system consists of a prime mover, water storage container, pump, hose, and valves. In Alberta, the prime movers include skidders, forwarders, high-flotation all-terrain vehicles, and tracked oil field support vehicles. These water delivery systems provide a cost-effective means of extinguishing fire in locations where water is limited, the pumping distance is great, a volume of water is required, or system mobility is an advantage.

Often during large wildland fires, fire crews aim to suppress all smouldering material 100 m (300 ft.) into the fire from a fuel break along the fire's edge. The terrain and forest cover in Alberta is variable, and the stability of prime movers used in these operations can be reduced due to slope and ground roughness.

Alberta Sustainable Resource Development (SRD) asked FERIC to develop a recommended minimum standard for tanks used to carry water on off-highway vehicles in support of wildfire operations. This report presents the recommended standards, which are intended to provide guidance to contractors building tanks and to improve the safety and effectiveness of water delivery on the fireline. Ultimately, however, the fire conditions and equipment availability will continue to dictate the hire of equipment for fire suppression.

Objectives

FERIC had the following objectives:

- Survey and describe off-highway equipment currently being used to deliver water for fire suppression in Alberta. Identify any limitations to this equipment's use on the fireline.

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1 The head fire intensity is the energy released per metre of fire front measured in kilowatts per metre.

- Develop a recommended minimum standard for off-highway, ground-based mobile water delivery systems used in support of Alberta wildland fire operations.

Equipment description

FERIC observed several types of equipment used in off-highway, ground-based water delivery systems.

Vehicles

- Skidders with mounted tanks – 1363 to 2726 L (300 to 600 gal.[2])
- Skidders pulling trailer-mounted tanks – 4362 to 6816 L (960 to 1500 gal.)
- Forwarders with mounted tanks – 1363 to 8407 L (300 to 1850 gal.)
- Tracked carriers with mounted tanks (e.g., Bombardier and Nodwell carriers) – 1363 to 9089 L (300 to 2000 gal.)
- Rubber-tired, high-flotation truck with mounted tanks

Tank concepts

- Permanent mounting
- Temporary mounting
- Materials
  - steel
  - plastic (polyethylene)
- Shape
  - rectangular
  - cylindrical
- With baffles, without baffles

Methods

FERIC photographed, measured, and recorded information on off-highway, ground-based water delivery systems used at the Chisholm, Dog Rib, Callington, and Duffield fires in 2001, and at Lost Creek in 2003.

Where possible, information on the pump, tank volume, attachments, and foam system was collected.

Observations

Equipment

The equipment that FERIC observed was suited for working in rough, steep, or soft terrain in areas where water for fire suppression was not readily available. The equipment can be classified into two categories:

- Equipment active in forest harvesting or in support of oil and gas development
- Older equipment that has been permanently modified and that is used specifically for wildfire operations

Most of the skidders that FERIC observed carried 1363 to 2273 L (300 to 500 gal.). The tracked carriers typically carried 1363 to 5000 L (300 to 1100 gal.). The tanks were usually constructed of metal, although a few owners had recently begun to use pre-formed plastic agricultural tanks. The water delivery systems were often simple, and required little training to operate and maintain. Few of the systems observed were capable of delivering foam.

Contractors generally focused on low-cost, functional design modifications to equipment. Several water-carrying systems observed were based on cylindrical petroleum tanks modified for fire application (Figure 1). However, in some cases the tank volume appeared inappropriate for the size of the prime mover. Currently, no guidelines exist in Alberta to help contractors determine tank size, pump, or foam system needs. However, the USDA Forest Service has a general guide-

[2] Unless otherwise noted, gallons in this report are imperial gallons.

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Figure 1. Used oil tank mounted temporarily on skidder arch for water delivery.

Figure 2. Illustration of a good tank design.

line for water-carrying capacity of skidder tanks based on flywheel horsepower, which is shown in the Implementation section of this report (Taylor et al. 2003).

In a well-designed tank system, the tank placement provides stability, the tank is attached to the skidder with steel pins, and the pump and attachments are easily reached from the ground. An example of a well-designed tank system is shown in Figure 2.

FERIC did not find any written policies on how forest officers should choose equipment, but it appeared that the officers drew upon their experience to evaluate and hire equipment based on appropriateness to the task at hand. The equipment was hired and utilized on an "as and when needed" contract basis. This meant that work was not guaranteed and an operator's ability to recover capital investment depended upon fire occurrence. The payment structure separated the rates paid for the prime mover and for the tank/pump system. Payment for foam systems was negotiated separately.

Generally, the off-highway, ground-based water delivery systems that are best suited to specific fire conditions remain on the work site for the longest period, providing the owner with higher revenue. A pre-registration program with the province gives hiring preference to those contractors who have had an equipment safety check, have signed contracts in advance of the fire season, and have a Certificate of Recognition.[3]

Water delivery

During the field survey, FERIC found that dewatering, trash, and pressure pumps were all used to supply water to the fireline. Most of these pumps were powered by small 2.6 to 5.6 kW (3.5 to 7.5 hp) Honda motors. A subsequent FERIC test found that Honda pressure pump models WH15 and WH20 were well suited for use in mop-up operations with a tank system under 2272 L (500 gal.) and with short hose lays under 170 m (500 ft.).

The warehouse staff working at the Chisholm fire noted that some of the contractors arrived at the fire with equipment incompatible for use with standard forestry discharge and suction hoses.[4] This meant their equipment could not be used effectively.

Licensed highway water trucks often use a 10 cm (4 in.) hose to transfer water to off-highway tanks. All fireline tanks should be equipped with a minimum 10 cm (4 in.) diameter or larger fill hole to allow venting for inflow water and to facilitate filling by water truck.

The primary tasks assigned to off-highway, ground-based water delivery systems included filling synthetic holding tanks (Figure 3) and directly supporting crews on the fireline. Some tank units are designed for filling on the fireline by a helicopter bucket (Figure 4). This is particularly useful when the travel distance for the ground vehicle is sig-

[3] More information about Certificates of Recognition is available at the following Government of Alberta Website: http://www3.gov.ab.ca/hre/whs/partners/cor.asp

[4] Al Walker, Supply Unit Leader, Chisholm Fire, personal communication, May 2001.

Figure 3. Water truck filling a synthetic portable holding tank (22 700 L) for use by skidder.

Figure 4. The tank mounted on the FMC forwarder can be filled using a helicopter bucket.

nificant or where very difficult terrain has potential to cause undue environmental damage not easily reclaimed.

Several firefighting crews were observed working on hot spots with transported water. In some cases, crews did not demonstrate effective and thrifty use of water. Considering the cost of delivering water, any gains made in transportation efficiencies can easily be lost if the water is applied ineffectively or wastefully by the fire crew.

When firefighters are working on hot spots, strategies or innovations that enable water to penetrate into fuels, rather than just on the surface, would improve effectiveness and should be considered.

The choice of nozzle is as important in water application as the pump and hose. Nozzles specifically designed for use with transported water could result in deeper water penetration and lower water volume requirements.

Few of the units observed were equipped to mix Class A fire foam. Operational and environmental concerns indicate the practice of batch-mixing foam in a water tank is not a suitable practice. As an alternative, several Class A foam injection systems are available on the market. Current Alberta Fire Protection Division policy recognizes wildfire foam as an invaluable fire suppression tool and that foam should be used to improve the efficiency of water application where it will reduce the overall cost of extinguishing the fire without causing health or environmental problems (Alberta Environmental Protection 2001).

Few of the tanks had water level indicators to help crews manage the water, and neither pump performance nor tank volume was marked on the tank. This information would enable crews to coordinate their mop-up activities more effectively. As well, few of the tanks provided a separate valve for filling backpack tanks. The ability to easily fill backpack tanks improves water utilization. Many of the rectangular tanks included an area where the forestry hose and supplies could be stored during transportation. Forestry fire hoses are expensive and subject to wear when dragged on the ground. Tank systems should include storage space for a minimum of 100 m (300 ft.) of forestry hose.

Secure attachment of the tank system to its carrier and prime mover is critical for the safety of firefighters and vehicle operators. Although this report does not recommend a particular method of tank attachment, several of the units observed attached the tank using chain or synthetic strapping (Figure 5). A common standard for temporary tank hold-down devices for highway transportation is a factor of 1.5 times the weight of the load.[5] The use of a skidder grapple to hold a cylindrical tank must include a method of ensuring the tank cannot be inadvertently released. These tanks should be held in place with pins rather than chains to ensure the tank will not shake loose or slip from the grapple.

[5] Federal Motor Carrier Safety Administration (U.S. Department of Transportation), Regulation 393.106(d).

Discussion

The primary benefits of a standard for off-highway, ground-based water delivery systems are increased effectiveness in fire operations and enhanced fireline safety. Two safety issues emerged in the field review of tank systems: the need for a professional engineer to assess changes in rollover stability with the addition of a water tank; and the need for fail-safe, temporary tank attachment methods. Responsibility for both of these safety issues rests with the equipment owner.

Rollover stability

The rollover of a skidder or tracked vehicle while working on a wildfire operation is rare. Operators and industry staff could not identify a rollover incident that was due to tank placement. However, rollover in the forest environment is a recognized risk. Regulation requires rollover protection systems on most harvest equipment to protect operators in the event of a rollover.

In Alberta, a Certificate of Recognition signifies participation in a health and safety program, and does not mean that the tank design and installation are certified or approved. Contractors are responsible for determining whether the installation of a water tank requires a professional engineer to certify that the modified vehicle remains within acceptable stability thresholds (Government of Alberta 2003).

Vehicle rollback on an incline has been identified as a potential source to dislodge an improperly secured tank. The protection of firefighters working with equipment depends on secure attachment of the tank.

FERIC conducted a trial in Hinton, Alberta to investigate the relationship between tanks and rollover. A Timberjack 460 skidder with a 2270 L (500 gal.) polyethylene tank was lifted from the front blade using a LinkBelt excavator to determine the angle or grade at which an adverse (i.e., while travelling up a grade) rollover could occur (Figure 6). This static test found that the skidder unit was very stable in all three conditions expected in the field (empty, half-full, and full). The test was stopped at a maximum grade of 60%. The configuration that was evaluated benefited from a tank placement with a low centre of gravity and with the weight forward of the rear axle.

Figure 5. Example of temporary tank attachment method.

Figure 6. Adverse rollover trial of a Timberjack 460 skidder with a 2270 L tank.

Oregon State University studied the stability of modified logging machines and developed a model for static stability.[6] The model looked at lateral and adverse stability for various fluid levels, but was unable to account for dynamic forces caused by sloshing of water within a tank, acceleration, or sudden movements from rough terrain. Therefore, the researchers suggested maximum slopes of 30% when travelling up the grade (adverse) and 20% when traversing across the grade (lateral). Lateral rollover is the higher risk.

6 Bielecki, C. 2004. Loggers and logging equipment for wildland fire suppression. Master of Forestry Thesis, Oregon State University.

In Oregon, the operation of rubber-tired skidders is limited to slopes of 30%,[7] while in British Columbia, such operations are limited to slopes of 35%.[8] These safety codes are for operations without modifications for water tanks. The inclusion of a water tank will change the skidder's centre of gravity and may reduce vehicle stability depending on the tank placement.

Until further research into dynamic stability is completed, Alberta should consider limiting the operation of skidders with water tanks to slopes less than 30% unless a stability assessment has been done. An operating limit of 30% slope is thought to be within the margin of safety for most tank designs on a skidder. The discretion of an experienced operator should ultimately determine the safe working limits of the machine.

Few of the tanks observed incorporated baffles to reduce the impact of water movement in partially filled tanks. The lack of surge control increases the risk of rollover. Plastic surge control baffles can be used in tanks to reduce the dynamic instability caused by water movement and provide a safe and cost-effective alternative to tank replacement of worn fixed baffles (Taylor et al. 2003). An example of a plastic surge control baffle is shown in Figure 7. The ellipsoid design works to deflect and dissipate the surge (kinetic energy) in a liquid load.[9]

The Nodwell tracked carriers were not evaluated for rollover stability. Generally, these machines operate in flat muskeg areas at low speed and have a low rectangular tank. The rubber track system also absorbs some of the dynamic force encountered under the rough ground conditions in fire operations.

Figure 7. Installation of a Surge Buster® liquid surge control unit (photo supplied by Linbir Holdings Ltd., Kamloops, B.C.).

Tank attachment

Temporary attachment of tanks to vehicles should have two independent means of securing the tank to the vehicle for the safety of the operator and firefighters. Pre-formed plastic tanks larger than 2270 L (500 gal.) should be enclosed in a cage to eliminate potential escape. Tanks placed on the flat-deck Nodwell carriers are susceptible to movement and must be cribbed with an angle iron or be hard mounted.

The design of tanks for wildfire operations should not require operators and firefighters to climb on the tank to fill it. Equipment storage should be accessible from the ground. The use of one stationary pump to fill the tank and discharge water will increase efficiency and safety. Where climbing onto the tank is required, slip-resistant paint should be placed on the tread surfaces. The use of longer suction hoses would also reduce the need to change pump locations, thus saving time.

Other issues

When firefighters are working on hot spots, strategies or innovations that enable water to penetrate into fuels, not just on the surface, should be considered. Because the nozzle design affects the spray pattern and volume of water delivered, specific nozzles may be most appropriate for off-highway, ground-based water delivery systems. For example, a forestry barrel nozzle with interchangeable 6.35 and 9.525 mm (1/4-in. and 3/8-in.) tips is suitable for mop-up operations.

Where practical, preference for the hire of a given contractor should be based on a recommended standard for Alberta being met. This preference could include supply of a Class A fire foam injection system.

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7 Oregon Occupational Safety and Health Standards (Oregon Occupational Safety & Health Division), Division 7: Forest Activities.

8 WorkSafeBC (Workers' Compensation Board of British Columbia) OHS Regulation, Part 26.16 (a).

9 From brochure distributed by Linbir Holdings Ltd., Kamloops, B.C.

Implementation

FERIC has recommended standards for the general operation, system design, plumbing and attachments, pump capability, and foam proportioning systems for use in off-highway, ground-based water delivery systems.

General operational requirements

- The water delivery system is designed with firefighter and operator safety in mind (see Appendix I).
- The operation of the water delivery system is consistent with the basic training that all firefighters receive, and uses equipment familiar to firefighters.
- The tank and water delivery system do not compromise the rollover stability of the prime mover and can be operated under normal conditions (less than 30% slope).
- The water delivery system components and attachments are compatible with standard SRD equipment.
- The system facilitates cost-effective water delivery by matching tank size to prime mover capability, by including appropriate plumbing, by using a pump with sufficient pressure (see Appenix II), and by including a foam proportioning system.

Recommended minimum system design

- Utilize a tank volume appropriate for the operating capacity of the prime mover (see Table 1).
- Where the centre of the water tank is positioned both above and behind the wheels of a skidder, surge control baffles and a stability analysis are recommended.
- The tank incorporates a water level indicator.
- The tank placement should not limit the operator's visibility.
- The tank incorporates a gravity drain to empty the tank with a 7.6 cm (3 in.) diameter dump valve.
- The tank capacity is written on the side of the tank.
- A three-digit identification number on the sides and top of the tank is visible from the air.

Plumbing and attachments

- 5 cm (2 in.) diameter discharge pipe
- Adequate tank filler ports and tank venting of 10 cm (4 in.) or larger (Figure 8)
- Pump discharge using standard 3.8 cm (1-1/2 in.) forestry hose with forestry quick connect couplings[10]
- 3.8 cm (1-1/2 in.) nozzle (adjustable and foam)
- Foam supply line shut-off valve
- 5 cm (2 in.) cam lock fittings on pump suction side (male) National Pipe Tapered (NPT) thread

[10] Standard (ULC S551-95) for forged external-lug quick connect couplings and adapters.

Figure 8. Example of tank filler ports for water and foam and venting stand pipe.

Table 1. Suggested skidder tank size based on flywheel horsepower (Taylor et al. 2003)

Flywheel horsepower	Tank capacity (US gal.)	Tank capacity (L)
69–82	50–100	190–378
83–100	101–200	379–756
101–135	201–300	757–1135
136–187	300–400	1136–1513
188–200	400–500	1514–1892

Figure 9. Example of well designed plumbing with appropriate attachments.

- 5 cm (2 in.) cam lock fitted (female) semi-ridged suction hose capable of reaching 6 m (20 ft.) with debris strainer prior to the pump
- 1.9 cm (3/4 in.) low-volume gravity feed spigot to fill backpack tanks
- Hose strangler
- Hose wrench
- Fire hydrant adapter 6.5 cm (2-1/2 in.) National Hose (NH) when involved in rural/urban interface fires
- Piping capable of withstanding pressures beyond the pump pressure shut-off
- Shut-off valve to allow pump removal while retaining water in tank

Figure 9 illustrates a well-designed plumbing system.

Pump capability

A balance between pressure and water volume is desired. A high-volume pump is preferred when filling the tank; however, pressure is needed during fire operations. Higher pressure at the nozzle results in increased water penetration into fuels during mop-up operations and a greater spray distance, but high-pressure pumps can be expensive to purchase and maintain.

- Pumps used for tanks under 2270 L (500 gal.) must produce a minimum of 379 kPa (55 psi) at shut off and deliver 227 L (50 gal.) per minute free flow.
- Pumps used for tanks between 2270 and 9090 L (500 and 2000 gal.) will require a pump capable of supporting two or more independent hose lines. A minimum requirement for these larger systems is 1379 kPa (200 psi) at shut off and delivery of at least 410 L (90 gal.) per minute free flow.

Note:
These pressure and volume numbers were developed from field observations by the author.

The pumping system should satisfy the following requirements:

- Can be used to fill the tank without being removed from the vehicle.
- Must be capable of producing 207 kPa (30 psi) from a 9.525 mm (3/8 in.) nozzle when connected to 91.4 m (300 ft.) of 38 mm (1.5 in.) fire hose and delivering a volume of 90 L (20 gal.) per minute.
- The pump used to fill the tank must be capable of doing so in 12 minutes or less.
- The pump must be capable of priming and drafting water through 6 m (20 ft.) of suction hose with a 4 m (13 ft.) lift.

Foam proportioning system – Class A fire foam

The Wildfire Foam Application Manual (Alberta Environmental Protection 2001) lists the scope and objectives of Class A foam use in Alberta.

The four foam injection methods are referred to as suction side, discharge side, around the pump, and batch mixing. The following are examples of foam proportioner units that avoid introducing foam into the pump:

- Robwen Hydro-Flo 100 and 500 foam proportioning systems
- Blizzard Wizard Around-the-Pump foam proportioner
- Fire-Trol FT-150 1-1/2 in. foam proportioning system
- Scotty Around-the-Pump 4071 and 4072 foam eductor/mixers

When producing foam using an in-line induction system, the pump should be located above the water suction valve on the tank. Otherwise, insufficient venturi is produced for foam production. Also, field staff have found that a 25.4 mm (1 in.) hose diameter is too small for mixing within the line. Sixty-one metres (200 ft.) of 38 mm (1-1/2 in.) hose is needed to produce foam.

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Appendix I

Considerations when designing and constructing water tanks

- Place tank where it will not obstruct the operator's vision.
- If skidder tanks are to be used on slopes greater than 30%, the maximum adverse grade and side slope capabilities should be analyzed and posted in a visible location for the benefit of the operator.
- Incorporate lifting eyes to remove the tank.
- The tank shape affects stability and strength. A cylindrical shape is the worst for stability but the best for strength.
- Include a stable platform on which to mount the pump, and place a containment area under the pump with removable absorbent pad to catch fuel or foam spills.
- Locate the pump at or above the water source to avoid head pressure for ease of starting the pump.
- Incorporate a carrying system to transport 91 m (300 ft.) of 38 mm (1-1/2 in.) forestry hose with attachments.
- Provide storage and protection for a 6 m (20 ft.) suction hose.

Appendix II

Water pump selection

Several pumps meet wildfire requirements, and selection should be based on tank volume, number of hose lines to be supported, and desired pressure (CIFFC 1997). Generally, four-cycle pumps are preferred because of their durability and simple fuelling. This is a partial list of pumps suitable for lower-volume tank units designed for wildfire use:

- Mercedes Textiles Ltd.: Wick 375, Wick 250, Wick 100, Wickman 100
- Wildfire Manufacturing: Wildfire Mark 3, Mark 26, Mini Striker, Striker 2
- Honda power pumps: WH15 and WH20