Evaluation of Performance of Helitorch Fuel During Cold Weather Operation

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Introduction

Alberta Sustainable Resource Development (ASRD) has been experiencing reliability problems with helitorch operations, particularly during cool/cold weather, that may be a result of fuel used for torching, or the torch itself. In particular, problems occurred with the helitorch at the Mt. Nestor prescribed burn during the spring of 2007. The torch worked well during test firing and then failed during operations.

ASRD organized a problem solving session for December 2007 and asked FPInnovations' Wildland Fire Operations Research Group to document the results. This report summarizes the tests done and provides recommendations for helitorch use in cold weather, as well as future research and documentation needs.

Objectives

- Evaluate the following fuels for performance with the Alberta helitorch:
  - Jet B
  - Jet A (only if Jet B showed promise)
  - Unleaded gasoline (low, mid and high octane)
  - 100 low lead aviation gas
- Determine if the helitorch mechanism was responsible for reliability problems.
- Compare cold weather gelling capability between Petrol Jel™ and Flash21.[1]

Background

Helitorch concept

The Alberta helitorch is slung below a helicopter on a 6.5 m sling. It operates by pumping gelled fuel past a propane igniter flame and dropping the burning fuel on the target (Figure 1). The torch assembly carries a 205 litre barrel containing gelled fuel. The ignition system includes an electronic sparking device that lights a propane flame that in turn ignites the gelled fuel. After activation by the helicopter pilot, the propane igniter is lit and gelled fuel is pumped from the barrel and ignited as it drops from the nozzle (Figure 2). The pilot is usually accompanied by an ignition specialist who directs where and how much fuel is dropped. A detailed description can be found in the Alberta Helitorch manual (Anon 1984).

Helitorch fuels

Until recently Jet B has been the primary fuel used for helitorch operations, mainly because it has been readily available. However, Jet B's availability may be decreasing and helicopters are now using Jet A fuel. Jet B was the fuel used at the Mt. Nestor burn and its low flash point was felt to be part of the problem. Jet A is not a ready substitute for Jet B as it does not gel very easily when using Petrol Jel™ and it has a higher flash point than Jet B (i.e, less volatile and therefore more difficult to ignite). Jet B is essentially Jet A (kerosene) with additives for cold weather.

[1] Petro Jel™ and Flash21 are produced and distributed by Astaris Canada Ltd.

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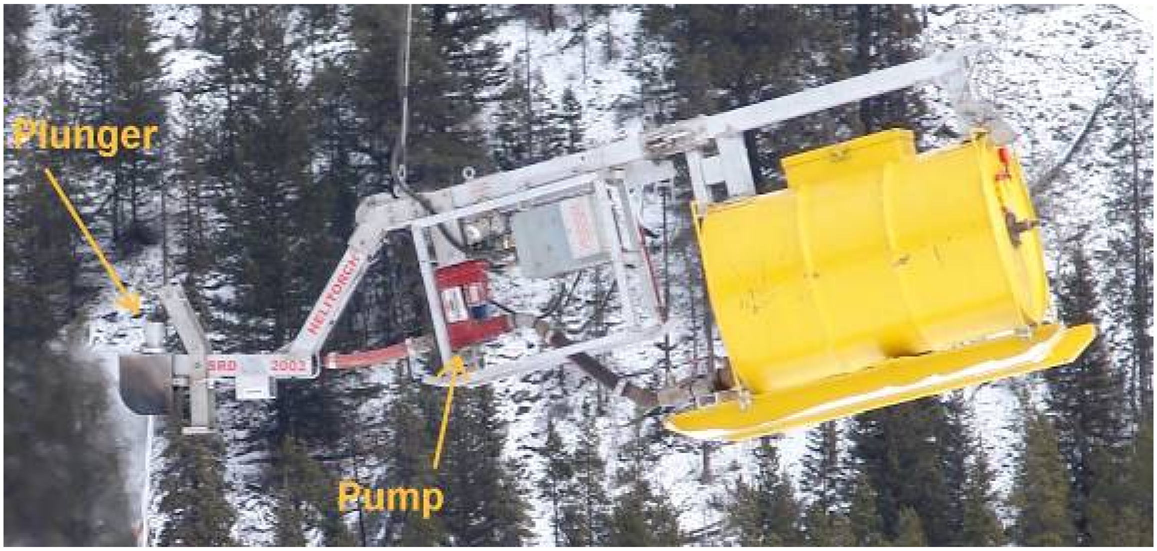

Figure 1. Alberta Heli torch.

Figure 2. Nozzle apparatus for the heli torch.

In reality, any fuel that can be easily gelled and ignited by the torch, and burns sufficiently in the canopy and on the ground to ignite forest fuels, can be used for helitorch operations. The 1984 Alberta Helitorch manual recommends using gasoline and warns that other fuels such as diesel and Jet B may not work all of the time (Anon 1984). Gelling agents are discussed in a following section.

The main characteristic that affects ignition is the fuel's volatility which is a function of its tendency to vaporize. The flash point is used as a surrogate measure of volatility as it indicates the minimum temperature at which a fuel will sustain ignition. In other words, enough vaporization is occurring for continuous combustion. Flash point is measured by different techniques which can affect the final value as shown in Table 1. The closed cup method can result in lower flash point values than the open cup (Table 1). However the numbers presented are meant for relative comparison among fuels only.

Vapour pressure is a second indicator of volatility. It is the static pressure of a gas in equilibrium with its liquid form (evaporation = condensation), and is temperature dependent. Higher vapour pressure equals greater volatility. It should be noted that the gelling agents may affect volatility by reducing the evaporation rate of the fuel, but we did not attempt to quantify this effect.

Octane is not an indicator of volatility, but rather indicates how much compression the fuel can undergo before spontaneous ignition takes place. Higher octane ratings indicate the fuel can undergo more compression before spontaneously igniting. These fuels are likely associated with having higher volatility because they are often used in high performance engines with much greater compression ratios compared to regular passenger vehicles. Aviation gas has a 100 octane rating, but is no more volatile than regular gas, and actually may be less volatile from a torch perspective because of additives used to reduce vapour lock (compare vapour pressure between Aviation gas and Unleaded gas).

Table 1. Fuel characteristics

Fuel	Flash point	Vapour pressure
Unleaded gas[1]	-40 C	76 – 103 kappa @ 38 C
Unleaded gas[2]	-50 to -38 C	<107 kPa @ 38 C
100 low lead aviation gas[3]	Not given	38 – 48 kPa @ 38 C
100 low lead aviation gas[4]	-50 C	38 – 48.9 kPa @ 20 C
Jet B[5]	-18 C	21 kPa @ 38 C
Jet A[6]	> 38 C	0.7 kPa @ 20 C

[1] Imperial Oil MSDS Number 8522. Flash point measured with open cup method.
[2] Petro Canada MSDS W102E. Flash point measured with closed cup method.
[3] Imperial Oil MSDS Number 03834
[4] Petro Canada MSDS 060-100LL, W118 Flash point measured with closed cup method
[5] Imperial Oil MSDS Number 8524
[6] Petro Canada MSDS Number W213m SAP:149. Flash point measured with closed cup method.

Gelling

Helitorch fuels are gelled so that they are stickier and burn longer compared to ungelled fuel. Stickiness is desirable in order to get burning fuel to "hang up" in tree canopies and results in better forest fuel ignition. Longer burn times are also desirable as this increases the probability of igniting forest fuels. Petrol Jel™ has been most commonly used with helitorch operations and works well with Jet B and gasoline in warmer temperatures. Petrol Jel™ can take a relatively long time (1/2 hour to 4 hours) to gel fuel depending on fuel temperature (Anon 1984). A new product called Flash21 can gel fuel much more quickly (usually within minutes) and also works with Jet A.

Test location and weather

The tests were done at the Livingston Gap fire base located 45 km north of Coleman, Alberta. Elevation at the fire base is 1440 m (4600 ft). Weather during the tests ranged from –15 C to 0 C. Winds were light to moderate at the fire base ranging from 0–15 kph. If the torch worked satisfactorily at the fire base then it would be used to ignite debris piles to the west of the fire base. Elevation at that location was 1780 m (5700 ft) and winds ranged from 30–50 kph.

Test procedures

The primary tests were done as if the torch were in operational mode, i.e., a full drum (200 litres) of gelled fuel was prepared and ignition tests were done from a hovering helicopter. Some additional gelling and ignition tests were done to supplement the airborne tests. Fuel mixtures tested were:

- Unleaded gasoline (87 octane) gelled with Flash21 (200:1)
- Unleaded gas (87 octane) gelled with Petrol Jel™ (1 jug)
- Unleaded gas (91 octane) gelled with Petrol Jel™ (1.5 jug)
- Jet B gelled with Flash21 (200:1)
- Jet B (50%) and Unleaded gas (50%) gelled with Flash21
- Unleaded gas (89 octane) gelled with Flash21 (400:1)
- Aviation gas (100 octane low lead) gelled with Flash21 (200:1)

After mixing, the torch would be connected to the helicopter and test fired at the fire base heli pad (Hover tests). The helicopter would hover so the torch would be 7-12 m above and then 20-30 m above ground for test firing. If successful the torch fuel would be used up to ignite debris piles located near the fire base (20-30 km to west).

Ground tests were also done to determine if ignition tests could simulate the torch ignition and to observe if the time to consume fuels was affected by gel mix ratio and fuel type. Samples of 300 ml and 100 ml were placed on the ground and ignited at the same time. Ignition was classified as instantaneous or delayed (meaning it took 1 to 2 seconds for the sample to be completely burning). Time to completely consume the samples was also measured. In addition to the seven fuels listed above, a mixture of Jet A and Unleaded gas was evaluated for ground based ignition potential only.

Two torches were used to determine if a particular torch might perform better than another, and they were evaluated by observation. Checks were made to ensure sufficient fuel was being pumped and that the igniter flame was working.

Results and discussion

Hover and debris pile burning tests

The helitorch tests demonstrated the effect of temperature on fuel ignitability for different fuels, one of the factors that may cause reliability problems. The observations for each test are outlined below.

<table>
<tr><th>Date</th><th>Fuel/gel</th><th>Fuel temp (deg C)</th><th>Air temp (deg C)</th><th>Wind (kph)</th><th>Time to gel</th></tr>
<tr><td>December 11, 2007</td><td>Unleaded gas (87 octane) - Flash21 (200:1)</td><td>-11.3</td><td>-3</td><td>5 – 10, gusting to 15</td><td>< 5 minutes</td></tr>
<tr><td colspan="6">Observations. The hover test produced a continuous stream of flaming gel and produced what turned out to be the best test of the session (Figure 3). The torch worked well igniting debris piles with no issues. Two strip runs of approximately 200 m were also done at an effective ground speed of 40 kph and were both satisfactory.</td></tr>
<tr><td>December 11, 2007</td><td>Jet B - Flash21 (200:1)</td><td>-4.8</td><td>-1.5</td><td>5 – 10, gusting to 15</td><td>< 5 minutes</td></tr>
<tr><td colspan="6">Observations. The hover test (7-12 m) was unsuccessful with no ignition. The propane bottle on the helitorched was changed and the hover test repeated. Some fuel did ignite and remain burning on the ground, but there was no stream of flaming gel as with the previous test. It was deemed a failure. An ignition test was done on the ground to compare the gas and Jet B and the gas was observed to ignite instantaneously while the Jet B had a delayed ignition.</td></tr>
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Figure 3. Torch operation showing desirable performance.

Date	Fuel/gel	Fuel temp (deg C)	Air temp (deg C)	Wind (kph)	Time to gel
December 12, 2007	Jet B with 20 litres Unleaded gas - Flash21 (200:1)	-4	-0.5	0-10	na
Observations. The Jet B from the previous day was mixed with gas but did not result in a successful hover test. It should be noted that the torch used was different from the one used on December 11. However, during the test the igniter flame was clearly visible; therefore, the torch was not suspected of being the source of the problem.					
December 12, 2007	Unleaded gas (87 octane) gelled with Petrol Jel™ (1 jug)		-3	10-15	4 hours
Observations. This drum was first mixed on December 11 and some separation of the gas from the Petrol Jel™ was observed on the morning of the 12th. After re-mixing the fuel, the hover test was unsuccessful. The pressure was adjusted on the propane ignitor after which inconsistent ignition occurred during the hover test (at 7–12 m). The torch was then taken to the debris piles where it worked successfully. The torch was also tested at a nearby fire lookout cabin (2440 m/8000 feet) and worked satisfactorily. Two strip runs were also successful in conditions of 15-22 kph effective windspeed.					
December 12, 2007	Jet B (50%) and Unleaded gas (50%) - Flash21	-3.3	-1	10-15	< 5 min
Observations. Hover tests at 7–12 m and 30 m (torch height) were unsuccessful with the ignition flame clearly burning. The torch was not taken to the piles for additional tests.					

Date	Fuel/gel	Fuel temp (deg C)	Air temp (deg C)	Wind (kph)	Time to gel
December 12, 2007	Unleaded gas (91 octane) – Petrol Jel™ (1.5 jug)	-4	-0.5		2 hours
Observations. The hover tests were initially not successful due to an ignition problem with the torch. Once corrected the fuel did ignite but intermittently. The mixture was then flown to the debris piles where it worked successfully. No strip runs were attempted.					
December 13, 2007	Unleaded gas (89 octane) gelled with Flash21 (400:1)		-15	20 min	< 5 min
Observations. The hover test resulted in a continuous flame from the torch. Pile burning was successful.					
December 13, 2007	Unleaded gas (89 octane) gelled with Flash21 (200:1)				< 5min
Observations. The hover test produced intermittent flame but did work better with the torch at 20–30 m above ground compared to at 7–10 m. The torch initially failed then worked poorly and finally produced a continuous flame, and again worked better at higher altitude. Pile ignition was also intermittent, but it was not as good as the 400:1 test.					
December 13, 2007	100 low lead (aviation gas) gelled with Flash21 (400:1)	-17	-15	45 min	10-15min
Observations. The mixture did not thicken as much as a 200:1 batch (stringy rather than snotty). This test was repeated using a long line (30 m). Initial tests failed and fuel flow from the torch nozzle was observed to be less than expected. The plunger on the torch head (controls flow through the nozzle) was sticking. Normal function resumed after cleaning and lubrication. Hover tests with the 7–10 m line did not work but the same tests done with a long line were both successful with continuous flames to the ground. Controlling the torch on the long line was difficult; it would begin to sway and could not easily be positioned over debris piles.					
December 13, 2007	100 low lead (aviation gas) gelled with Flash21 (200:1)	-6	-5	< 5 min	8 min
Observations. This batch worked intermittently for the hover and pile burning. Hovering at 7–10 m did not work but did work well at 20–30 m. The same results occurred over debris piles where the fuel burned poorly at low altitude and better higher up (30 m).					

It is clear that fuel characteristics played an important role in helitorch performance. Unleaded gas had the highest volatility of the fuels tested and also performed the best. Aviation gas (100 low lead) was better than Jet B and Jet B/Unleaded gas mixtures but still problematic. The likely reason for poor performance is the additives used to reduce vapour lock that would also affect ignition by the torch. We also noticed that ignition appeared to improve after several attempts as if the torch nozzle had to be warmed up first when using the 100 low lead fuel.

It appears that the torch height above the ground did affect performance. The torch worked better at 20–30 m above the ground compared to 7–12 m, although in some cases (e.g., the first test with gasoline) it worked well at any height. Helicopter ground effects could potentially affect helitorch performance. The term refers to increased lift when the machine is within 2/3 of the rotor diameter to the ground as the helicopter creates increased air pressure underneath it. It is unlikely that ground effects were causing extra lift during the hover tests because the helicopter was always at a height of greater than 2/3 rotor-diameter above ground, but they may have been strong enough to affect fuel ignition. Logically, rotor downwash (airflow beneath a hovering helicopter) effects decrease with distance from the helicopter and ground effects and downwash can have a combined effect on airflow and turbulence underneath the aircraft. It was not the purpose of this report to quantify air flow and pressure effects on the helitorch, but our observations indicated that these factors likely affected torch performance. We tested the long line to determine if increasing the distance between the helicopter and the torch would change the performance. A 20-m long line did not appear to improve performance and would not be useful for operations at any rate because of difficulties in positioning the torch and preventing it from swaying.

We had difficulty observing if the torch's propane igniter performed consistently throughout all of the tests, and this problem also occurs operationally. A frequent remedy is to replace propane bottles during operations and this technique appeared to work at least once during the tests. When working well (continuous flame production) the torch/igniter did not seem to be affected by effective wind speed (air + wind speed) during the strip run tests. The igniter flame may have been affected during the low altitude tests due to down wash and ground effects but it was difficult to make consistent observations.

The gelling agents both worked. Flash21 consistently gelled the fuel within 5 minutes of mixing except in one test. Petrol Jel™ required close to 4 hours to complete the gel and this delay has been a problem during operations. As well, personnel sometimes add more Petrol Jel™ than needed in order to speed up the process. If care is not taken, the mix can eventually get too thick to flow well through the torch's pump.

Two drums were left overnight (Unleaded gas with Petrol Jel™ and Jet B/10% Unleaded gas with Flash21) on the night of December 11th. Some separation occurred with the Petrol Jel™ and none with the Flash21. Mixing temperature for Flash21 did not affect performance, but Flash A does freeze at –15 to –20 C. It thaws quickly and is still effective after freezing.[2]

Ground based ignition tests

Ignition tests reflected the higher volatility of Unleaded gas compared to Jet B (instant versus delayed); however, burn time among samples did not vary greatly (Table 2). Only two tests were done and without replicates. We thought the ground based tests would indicate how the fuels would perform in the helitorch (Figure 4), and samples with instantaneous ignition were expected to work well in the torch. This was not the case with the Jet B (50%)/Unleaded Gas (50%) mixture. The Jet A (50%)/Unleaded Gas (50%) was not tested extensively as it is less volatile than Jet B and we already knew it did not work well at the temperature ranges during the study. It did gel readily (Flash21) and ignited easily although with a delay. Jet A could be used by ground crews to help ignite debris piles but it is not recommended for use with the helitorch because it is too difficult to ignite. Burnout time (time for complete consumption of the sample) is important as it affects how well the fuel can ignite forest fuels and forest debris. Too rapid a burnout time could mean canopy and surface fuels will not ignite.

Table 2. Ground ignition test and burnout time.

Fuel	Sample size	Ignition	Burnout time
Unleaded gas (Petrol Jel™)	300 ml	Instant	7 min
Jet B (50%)/Unleaded gas (50%) – Flash21	300 ml	Instant	7 min
Jet B (90%)/Unleaded gas (10%) – Flash21	300 ml	Delayed	7 min
Unleaded gas (Petrol Jel™)	100 ml	Instant	4.7 min
Jet B (50%)/Unleaded gas (50%) – Flash21	100 ml	Instant	5 min
Jet B (90%)/Unleaded gas (10%) – Flash21	100 ml	Delayed	5.5 min

[2] FPInnovations staff successfully mixed gelled unleaded gas within 5 minutes at –25 Celcius at another test on January 08, 2008.

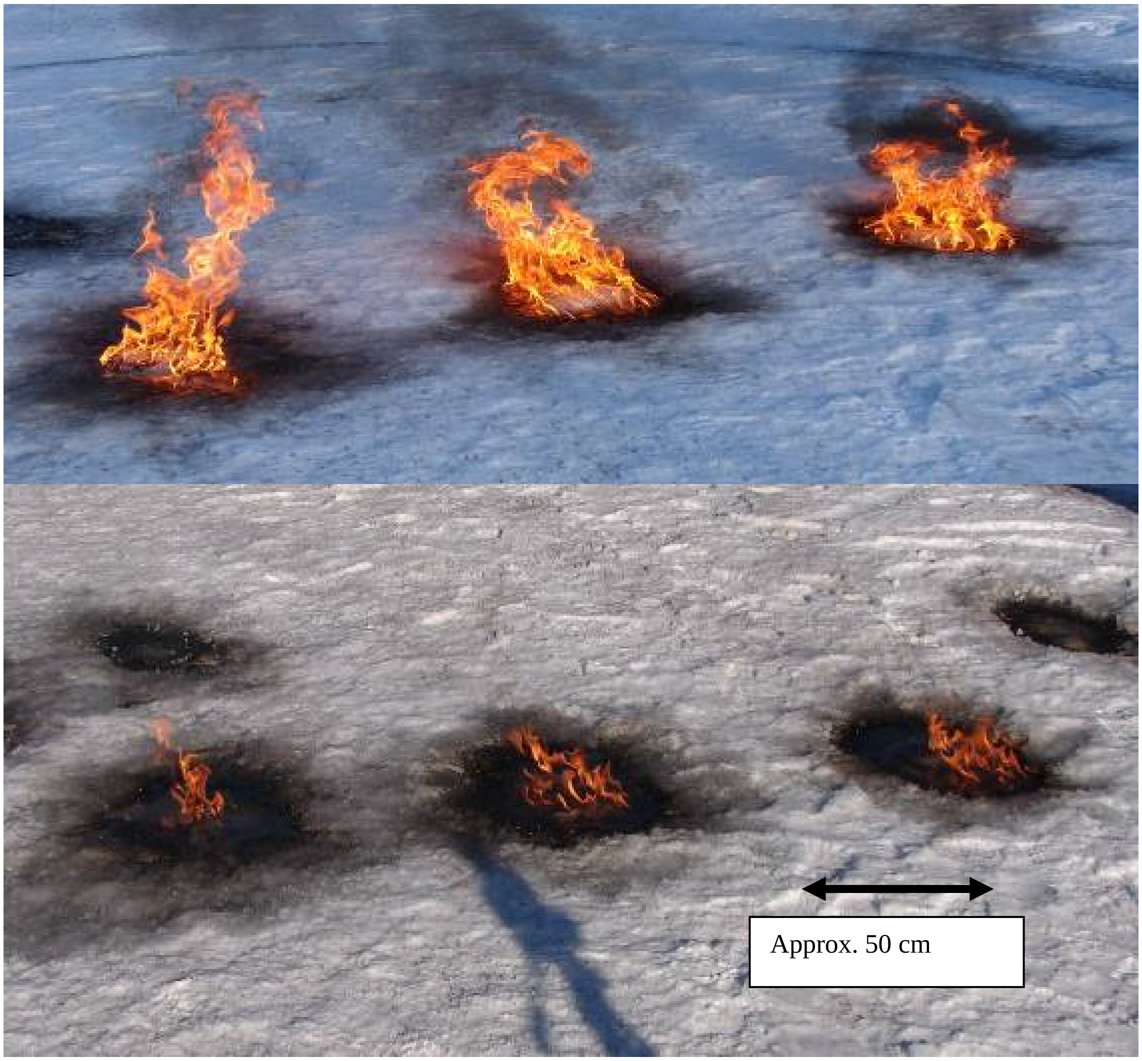

Figure 4. Ground ignition tests – 300 ml samples. Top – after ignition. Bottom – almost burned down.
Left = Unleaded gasoline, Center = Jet B/unleaded gasoline (50-50 mix), Right = Jet B + 10% gasoline.

Recommendations

Operational use

Unleaded gasoline (any octane) was the best performer, and met the expectations of the ignition specialists present at the test. Jet B, Jet B/gas mixtures and aviation gas (100 low lead) are suitable at warmer temperatures (Table 3). Flash21 was far faster at gelling all of the fuels and did not result in any settling after mixtures were left over a 12 hour period.

Downwash and ground effects may negatively affect helitorch performance. If this is suspected, the torch altitude should be increased.

The helitorch itself did not appear to affect performance, although a sticky plunger demonstrated the need for frequent servicing during operations.

Additional data collection and torch improvements

Jet B, Jet B/gas mixtures and aviation gas performance should be documented at warmer temperatures although it is well known that Jet B will work satisfactorily above 20 C. It would be especially valuable to document aviation gas at warmer temperatures. Gasoline does not appear to be available in 205 litre drums (D. Pitt pers. comm.), unlike Aviation Gas and Jet B, and this can be an important limitation. These drums are the easiest way for

Alberta SRD staff to move fuel, especially to sites that are helicopter-only accessible. The potential, or limitation of ethanol blended gasoline were not explored, and these blends are becoming more common.

Table 3. Recommended operating temperatures and elevations

Fuel	Temperature range	Elevation
Unleaded gasoline (any octane)	No limit	No limit
Jet B [a]	> 15 C	Max 3600 feet
Jet B/Gas mix (50/50)	Not recommended [b]	
Aviation gas (100 LL) [a]	-5 to 30 C	No limit
Gel		
Petrol Jel™	> 15 C	No limit
Flash21	No limit (Flash A freezes below – 20 C)	No limit

[a] Note: the recommendations for Aviation gas and Jet B were based on the experiences of the testing group, which included four ignition specialists.

[b] Having to mix drums of different fuels adds unwanted complexity to helitorch operations, therefore mixed fuels are not recommended for operational use.

Hancraft Aeromotive (Geoff Hancock) and FPInnovations plan to continue development of an in-line mixing system for Flash21 and to test an electronic igniter for the torch. FPInnovations has had success with an electronic igniter on a terra torch; this might work with the helitorch and remove reliability problems associated with the propane igniter. We also hope to instrument an operational helitorch with thermocouples to investigate nozzle temperature profiles and possibly to mount a small camera to monitor ignition and igniter flame behaviour.

Conclusions

Operational cold weather (-15 to 0 C) tests of the Alberta helitorch indicated Unleaded gasoline (any octane) is an effective fuel. Aviation gas (100 low lead), Jet B and JetB/gas mixtures should only be used during warmer temperatures. The burnout time for these fuels appears to be similar. Flash21 gels them within 5 minutes compared to Petrol Jel™ which takes several hours when at low temperatures. Helitorch altitude and distance from the helicopter can also affect performance—higher altitudes (minimum of 20–30 m above ground) result in better torch fuel ignition. We did not find any reliability issues with the heli torch itself although the need for regular maintenance is stressed. There may be potential to improve the torch through the use of an electric igniter and in-line mixing of fuel and Flash21 gelling chemicals.

Reference

Anon. 1984. Alberta Forest Service, Forest Protection, Helitorch Manual. Alberta Energy and Natural Resources, Forest Service. Edmonton, Alberta.

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