

**Final Report
Terra Torch Accident
Pack Creek Prescribed Fire
Manti-La Sal National Forest
April 27, 2007**

Executive Summary

On Friday, April 27, 2007, a National Park Service (NPS) employee, was injured while attempting to resolve a mechanical malfunction on a NPS-owned terra torch. The NPS was providing three (3) firefighters and the terra torch as interagency assistance to the Manti-La Sal National Forest in support of the Pack Creek prescribed fire project. This report was prepared in accordance with requirements for non-serious wildland fire accidents, described in the *Interagency Standards for Fire and Fire Aviation Operations* (NFES 2724).

At the time of the accident, the terra torch was staged and preparing for use on the prescribed fire. The employee had been actively diagnosing a malfunction on the terra torch. He had started the machine to test the system but because the clutch had not engaged he had reached around behind the belt and pulley system in an attempt to troubleshoot the malfunction and potentially free the clutch so that the pump could engage. During this action, his finger engaged the belt and pulley system, causing a digit amputation to his right ring finger and thrust this hand away and into the metal housing causing damage to adjoining fingers.

The accident was caused by an unsafe act, a result of momentary lapse of situational awareness by the employee. However, the employee was not adequately trained in the operation of the terra torch, nor did adequate policies, procedures, or controls exist that may have prevented the accident.

In addition, the investigation team found an interrelationship between many of the contributing factors, suggesting a systemic failure within the organization to provide adequate training and certification for operation of the equipment. This report includes several recommendations that should be placed in order to prevent future accidents while operating this equipment.

Narrative

Interagency assistance from Mesa Verde NP to the Manti-La Sal NF was requested on April 23, 2007. On Friday, April 27, 2007, three members of the Mesa Verde NP Helitack crew, along with the NPS-owned terra torch (mounted on a trailer), were mobilized to assist the Manti-La Sal NF with a prescribed fire near Moab, Utah. The planned assignment for these personnel and the terra torch was to assist in blacklining a burn unit on the Pack Creek Prescribed Fire. One of the crewmembers had received some training and was experienced in operating the terra torch.

The terra torch was function-tested and checked prior to departing from the park on April 27. Travel to Moab from Mesa Verde NP was safely accomplished and the NPS employees attended the pre-burn briefing scheduled for 8:30am at the Moab BLM Fire Operations Center. Following the briefing, at approximately 9:00am, the NPS employees stopped at a gas station to fill up the terra torch. After fueling, the pump on the terra torch was started at the gas station, in an effort to mix in the new gas with the mixture already in the tank. However, on this occasion, the clutch assembly and pump did not work correctly, but a decision was made to proceed toward the burn site and check the pump again prior to arriving at the burn unit.

When the employees arrived at the turnoff to the burn site from Highway 191, they parked and proceeded to get the torch (and pump) in operable condition. One of the employees was positioned on top of the tank, stirring the gas and gel mixture. The other two employees, one of which had experience operating the torch, were positioned at the rear of the terra torch. The individual who had been trained in operating the terra torch determined that the clutch was not functioning correctly.

While the motor on the torch was running, at approximately 10:20am, the individual reached behind the pulley/clutch assembly. Moments later, as he was attempting to diagnose and correct the malfunctioning clutch, he engaged a portion of his right hand with the pulley/clutch assembly, resulting in the amputation of the distal digit on his ring finger, as well as lacerations to his long finger.

The two NPS employees working with him on the terra torch immediately provided medical actions, one of which was a registered nurse with experience in emergency care, who directed the medical response. The patient was stabilized, the wound was wrapped, the amputated portion of the finger was retrieved (and preserved), and the patient was placed on a flow of oxygen via nasal canula. An ambulance was dispatched to the accident site, and transported the patient to the hospital in Moab. The patient was accompanied by his co-worker who directed the medical response, who remained with him until he was transferred to orthopedic specialists at Mercy Medical Center in Durango, Colorado.

Investigation Process

Immediately following the accident, personnel from the USDA Forest Service and National Park Service coordinated the formulation of an investigation team in accordance with the *Interagency Standards for Fire and Fire Aviation Operations* (NFES 2724). Once configured, the investigation team inspected the terra torch, conducted multiple interviews, and reviewed a number of related documents, with consideration for human, material, and environmental factors. However, environmental factors (weather conditions, as well as accident site conditions such as elevation, slope, aspect, vegetative cover, and related elements) were determined to be noncontributing to the accident and were removed from further consideration.

Findings

The findings were developed from factual information obtained by the investigators:

❖ Direct cause of the accident

- **Finding:** The accident was caused by an unsafe act, a result of lapse of situational awareness by the employee, who put his hand into the moving parts while he was troubleshooting a mechanical malfunction, namely, the clutch would not engage. His fingers were drawn into the belts and pulley/clutch assembly.

❖ Indirect causes which contributed to the accident

➤ **Findings:** Equipment Factors

- The precise and definitive reason for the equipment malfunction at the time of the accident cannot be determined. However, while there were several possible reasons for the equipment malfunction, the most probable cause was insufficient charge to the 12-volt (vehicle type) battery. The torch itself and clutch mechanism operate on a 12-volt system. The clutch will not operate if the battery has insufficient charge. NPS personnel have subsequently charged the battery and report that the mechanism now works.
- The terra torch was not properly guarded according to OSHA CFR 1910.219. There was a top cover that offered some protection; however, a person could still put their hands into the moving parts from the front, even when the top was closed.
- Some terra torches (such as the BLM-owned terra torch that was used the following day) have a box that covers all of the moving parts while the machine is in operation; however, if problems arise, most operators would probably lift the box (or “hood”) to troubleshoot a malfunction, exposing the moving parts.
- The clutch, according to the interviews, had not malfunctioned prior to the accident. The machine had been used earlier this year. The employee stated that he felt the machine was clogged. He was trying to tap on the clutch to see if it would operate and free the perceived clog when his hand was caught.
- The investigation team found two (2) frequent problems with terra torches; first, if the gel isn’t mixed properly, they clog up, and second, if the battery is not properly charged the clutch will not engage. On the Pack Creek Prescribed Fire, the BLM terra torch that was used the day following the accident was malfunctioning until they replaced the battery.
- There was no reference operating manual for the terra torch. As a result, there was no written document that would be an important source of information regarding the need to periodically charge the battery. In combination with the limited training that the employees received, the result was a lack of knowledge regarding the importance of having a sufficiently charged battery prior to operation. Additionally, no written records of

equipment operation, such as an operating log, were maintained that might indicate that the battery was due for charging.

- The Job Hazard Analysis (JHA) being used for the terra torch was a subsection of a larger “Pile Burning” JHA used for other similar prescribed fire projects. The JHA did not specifically mention potential hazards of getting hands or fingers caught in the belts and pulley/clutch assembly.
- **Findings: Human Factors**
 - The NPS employees were motivated to provide interagency assistance to the project and consequently had intentions of providing operable equipment and services to the prescribed fire.
 - The park did not maintain a written record of the training and certification process for employees to operate the terra torch.
 - Interviews with NPS personnel who had operated the machine on previous assignments revealed that although they had successfully operated the torch prior to the accident, they really didn’t understand that the clutch operated on a 12-volt system, and that the clutch would not work properly if the battery was not sufficiently charged.
- ❖ Other findings which, if left uncorrected, could lead to future accidents
 - **Findings: Human Factors**
 - The investigation team found conflicting statements between the employees and their former supervisor regarding training and qualifications to operate the terra torch.
 - **Findings: Equipment Factors**
 - The tank capacity on the terra torch is estimated to be approximately 180 gallons. This exceeds the 119 gallon maximum tank capacity established by Colorado Department of Transportation and thus requires special endorsements on driver’s licenses and appropriate placards.
- ❖ Findings that are not direct casual or contributing factors
 - **Findings: Human Factors**
 - There were no apparent violations of agency work/rest guidelines by the injured employee or his co-workers, and thus employee fatigue was discounted as a contributing or causal factor.
 - There was no written record or “resource order” using the Resource Order and Status System (ROSS) for the personnel and equipment from Mesa Verde NP to assist the Manti-La Sal NF with the prescribed fire.
 - **Findings: Equipment Factors**
 - A small Briggs and Stratton 4-cycle engine is used on this terra torch that turns a pair of belts, which drive a pulley and clutch mechanism, which in turn, operate an impeller-driven pump. The clutch is engaged by moving a toggle switch that had three positions; off, mix, or torch. The clutch performed two important functions when engaged with the toggle switch; in the “mix” position, the pump circulated the gasoline mixture within the tank; in the “torch” position, the pump flows the gasoline mixture into a trigger

activated delivery wand shaped like a hand-held rifle. The torch itself and clutch mechanism operate on a 12-volt system that requires periodic recharging from a separate and external battery charging device, provided by the equipment owner.

Discussion

The findings of this report were based on personal interviews, document review, and inspection of the equipment. The primary cause of the accident was human error and the result of the employee committing an unsafe act. The contributing factors to this accident are diverse but are primarily centered on the safe operation, training, and maintenance of the terra torch. There are interrelationships between many of the contributing factors.

Recommendations

Action Recommended	Responsible Office
Install a guard over the belt and pulley/clutch assembly.	Mesa Verde National Park
Develop a Job Hazard Analysis for the terra torch, including, but not limited to, mitigation of hazards associated with the potential for getting hands or fingers caught in the belts and pulley/clutch assembly, as well as a list of personal protective equipment for individuals assigned to operating the equipment.	Mesa Verde National Park
Develop an operator's manual for the terra torch with specific directions for all components of the equipment, including, but not limited to fueling, mixing, firing, periodic battery charging, and other maintenance.	Mesa Verde National Park
Maintain an operating log (record) for the terra torch.	Mesa Verde National Park
Develop and maintain a training and certification program for individuals who may be assigned to operate the equipment.	Mesa Verde National Park
Retrofit the equipment to reduce the tank capacity, in order to enable safe and efficient mobilization.	Mesa Verde National Park
In order to legitimize the mobilization of firing apparatus and operators, ensure that the mobilization process for the terra torch and accompanying personnel is documented using the Resource Order and Status System, in accordance with national and regional mobilization guides.	Manti-LaSal National Forest Mesa Verde National Park

Conclusions and Observations

The investigation team has determined that the accident and injury were the direct result of human error. However, as supported by a number of the findings determined to be contributing factors, this accident would likely have been prevented if adequate policies, procedures, or controls were in place.

An effective accident investigation will look at the "true" or deep-root causes, which are virtually always organizational and cultural. Assuming the operator was well intended and competent, then essentially any other employee could have done the exact same thing with the same or worse outcome.

In this case, the investigation team found an interrelationship between many of the contributing factors, suggesting a systemic failure within the organization to properly train and certify employees in operation and maintenance of the terra torch. Additionally, the equipment was not delivered to the park with adequate guarding surrounding moving parts, nor was the equipment delivered with a tank capacity within recommended thresholds for safe and efficient mobilization.

It will be essential that the staff at Mesa Verde National Park address the aforementioned actions before the terra torch is brought back into operational use. This is an excellent opportunity for the park to demonstrate resilience and leadership in safe practices by developing a set of protocols for terra torch operation that can be shared with other interagency wildland fire management partners.

The Manti-LaSal National Forest will use the Resource Order and Status System for ordering resources.

Maps/Photographs/Illustrations

Available on request

Appendices

None