New Firefighting Nozzles Suppress Wildfires More Quickly

Wildfires are one of the biggest environmental threats, burning millions of acres worldwide each year. Our ability to suppress wildland fires relies on the availability of water, and fire hose nozzles play an important role. As water travels from nozzle to fire, some of the water absorbs heat and evaporates, cooling the fuel mixture (*e.g.,* thick brush and grass). Additionally, on conversion to steam, water expands 1,700 times, diluting the fuel vapors and inhibiting combustion. The percentage of water that absorbs heat and evaporates is called its evaporation efficiency. Therefore, it is critical to maximize the evaporation efficiency of the water stream.

Currently, firefighters use two types of nozzles: smoothbore nozzles and combination nozzles. Smoothbore nozzles generate cylindrical water streams with a long reach. Cylindrical patterns have low coverage and small surface area per unit volume, which results in a comparatively low heat absorption rate and a low evaporation efficiency. Combination nozzles have an internal baffle that creates conical stream patterns with a relatively large surface area. However, their conical patterns direct water away from the target and have a short reach, and turbulence made by the nozzle's baffles creates small water droplets that are unstable in wind and may not reach the fire.

HEN Nozzles Inc., a Hayward, CA-based startup funded by the U.S. National Science Foundation (NSF), has designed nozzles that maximize the evaporation efficiency of water streams. Fire suppression analysis showed that an ideal water stream should have forward velocity to achieve a long reach, diverge into a wide pattern at the target, and be composed of large water droplets. A diverging-rectangular stream pattern, or "blade" pattern, with low turbulence can meet these requirements.

To analyze water flow in nozzles, HEN used computational fluid dynamic simulations. The research team found that a continuous reduction in cross-sectional area is critical to maximizing the fluid velocity. They also discovered that to create a diverging pattern while reducing the cross-sectional area, a simultaneous increase in surface area was required. HEN's design met these objectives by simultaneously converging and diverging the flow pathway in perpendicular directions, such that the rate of convergence was greater than the rate of divergence. HEN developed nozzle actuators that can modulate the divergence angle of the water stream as it exits the nozzle. These actuators are placed outside the fluid pathway to minimize turbulence and are operated by simply rotating the nozzle shell. With these innovations, HEN created an adjustable smoothbore nozzle.

To test nozzle performance, HEN conducted live vegetation and structural fire tests involving traditional smoothbore nozzles, combination nozzles, and HEN adjustable smoothbore nozzles with a blade stream pattern. Compared to existing state-of-the-art nozzles, HEN's nozzle increased suppression rates by up to three times, while reducing the amount of water needed by two-thirds for vegetation fires and one-half for compartment fires. Wildfires can grow exponentially. If the growth rate of a major fire like the 2021 Dixie Fire could be reduced by just 10%, containment time could be reduced by weeks, saving billions of gallons of water, reducing suppression costs by hundreds of millions of dollars, and preventing billions of dollars of property damage.

HEN nozzles are initially available in high-fire-risk regions such as the Western U.S., where prototypes are in use and sales are expected to begin in 2023. These nozzles will enhance the fire suppression capabilities of fire departments in those regions without requiring large capital investment.

Eric Guida, a retired fire captain from the Sacramento Fire Department, explains, "Until now, firefighters had to choose between a combination nozzle, with less than adequate droplet size, and a smoothbore nozzle, which has the desired droplet size but with little versatility. HEN nozzles give the firefighter the best of both worlds: a nozzle that delivers large droplets of water and the ability to adjust the stream and place more water where it needs to be with less exertion by the firefighter." CEP

▲ The blade pattern of the HEN nozzle was able to suppress a fire in eight seconds using six gallons of water (left). This suppression rate was three times faster than the traditional smoothbore nozzle (right).

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