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# The use of laser scattering and energy harvesting technology for fire evacuation

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ABSTRACT

When a building is on fire, the building may be dark because of a power failure or heavy smoke. In this case, the people inside the building may lose their sense of direction and may possibly become trapped in the building. Although there may be some emergency lights and indicators located at specific corners of the building, they may not be adequate to direct the occupants to a safe place, or they may be inoperative because of a failure of the emergency devices. In this study, laser scattering and energy harvesting technology, integrated with automatic sprinklers, is proposed to solve the problem of fire evacuation when there are inadequate or faulty emergency lights or indicators. When the automatic sprinklers are activated by the fire, the water flows through micro-turbine generators attached to the sprinklers, which generate electricity that is used to supply power to the illumination system. The illumination system uses a laser projector with a holographic pattern to project evacuation signs and highlight exit locations. It is believed that with this technology, the possibility of survival and the chance for rescue are increased. The energy harvesting technology proposed in this study has another innovative benefit in that no battery or utility wire is needed.



## 1. Introduction

### 1.1. Background

When a fire occurs in a building, the indoor illumination for the occupants trying to escape from the fire is often lost because of a power failure or the fire plumes. People can become trapped in this environment because the darkness, the spray from the sprinklers, the smoke, and even the loud alarm sounds can cause them to become disoriented. If they cannot escape during the initial fire, they may miss the "golden" time to escape and die. It is highly possible that people lose too much time in finding the way out because they collide with surrounding objects and lose their sense of the direction. Many victims of fires were found lying very close to an exit. The statistics in Canada showed that 86% of fire deaths occurred in houses, representing 45% of the total number of fires and 45% of the total fire loss (Annual Report, 1993). Most factories, large commercial buildings, and residential tall buildings are required to install initial firefighting equipment to help control and put out fires as soon as possible to reduce the loss from the fire. Initial firefighting equipment includes manual and automatic types. The manual equipment, such as fire extinguishers and fire hydrants, is often ineffective in controlling the initial fire because the personnel are unskilled. In this case, the fire might expand to an uncontrolled condition. Therefore, a certain class of buildings is further required to install automatic equipment according to national regulations. The most common automatic firefighting equipment is the automatic sprinkler suppression system, and the most common automatic sprinkler suppression system is the water suppression system.

The water suppression system has had outstanding results in putting out fires automatically during the initial fire period. According to an investigation by the National Fire Protection Association (NFPA), only one or two automatic sprinklers can extinguish a fire. Even fires in factories can be extinguished effectively by less than ten automatic sprinklers. Therefore, the water suppression system is often used in office buildings, department stores, parking areas, factory buildings and warehouses.

In addition to the requirement of extinguishing a fire by a water suppression system, sufficient illumination is additionally required to direct occupants to escape the fire successfully. However, the illumination guides can be relied upon only if they have uninterrupted power when the utility power has failed.

In the present fire protection regulations, the emergency lighting devices and the evacuation indication devices are installed near the exits, the stairs and important corners. However, if the present lighting devices are damaged by fire or blocked by smoke plumes, they will not assist substantially in the evacuation. Furthermore, most emergency lighting devices are powered by a battery. The

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emergency illumination function will be lost if the battery has failed.

In a previous study (van de Hulst, 1981), it was shown that the dimming of light is caused by absorption and scattering of light. In the fire environment, the large quantities of smoke absorb and scatter the evacuation lights, which reduce the chance of survival for people inside the burning building.

### 1.2. The installation and configuration of the automatic sprinkler system

The automatic sprinkler system is composed of a piping system, both above-ground and underground, that conforms to engineering standards for protecting the safety of life and property. The automatic sprinkler piping system above the ground is fixed under the roof of the building, structure or specific area. The piping network of the sprinklers is designed according to water power calculations. The automatic sprinklers are systematically installed in the network. Once the heat of a fire is sensed, the automatic sprinkler opens to spray water into the fire area to extinguish the fire. In an automatic system, there is at least one water source that can supply water automatically. The automatic sprinkler piping system is connected to the water source with a water control valve and a water flow detection device between them. When an automatic sprinkler is activated to spray water, the device detects the flow of water, which then switches on the siren to sound an alarm (Standard Report, 2002).

To satisfy the different demands of various fire scenarios, automatic suppression system designs are categorized as a wet pipe system, as shown in Fig. 1; a dry pipe system; a pre-action system; or a deluge system (Standard Report, 2002).

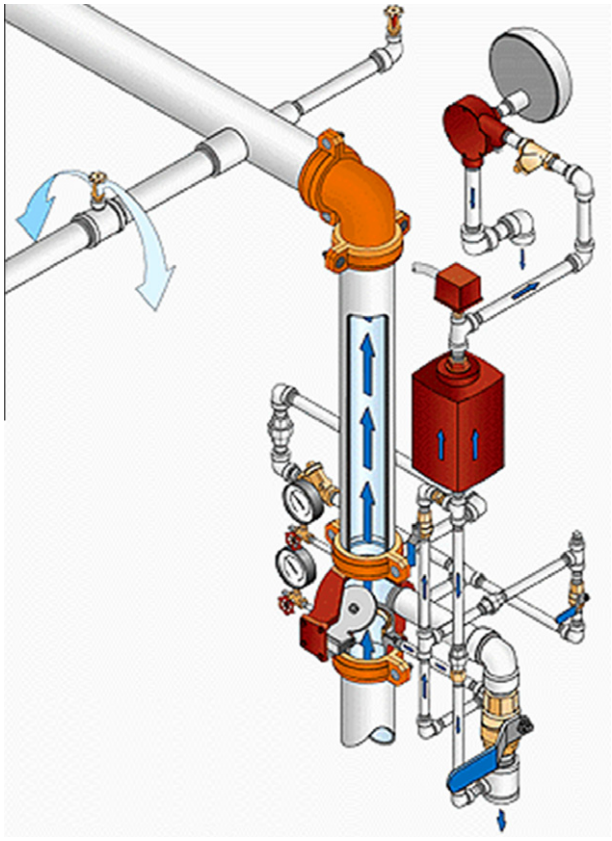

**Fig. 1.** Wet piping system (Standard Report, 2002).

The wet pipe sprinkler system is installed more often than all other types of automatic suppression systems. It is the most reliable because it is simple configuration, with the only operating components being the automatic sprinklers and the automatic alarm check valve (commonly used, but not always). An automatic water supply provides water under pressure to the system piping.

### 1.3. Automatic sprinklers

Automatic sprinklers are also called fire sprinklers, or simply sprinklers. A fire sprinkler is the part of a fire sprinkler system that discharges water when a fire is detected. The fire detection method most widely used is when a predetermined temperature has been exceeded.

The number of sprinkler types has been increased with the continuous development and innovation of fire-protection technology. However, the basic structure has remained nearly the same. Sprinklers are composed of deflectors, heat-sensitive glass bulbs, caps and orifices, as shown in Fig. 2. The structure of a sprinkler directly determines the sprinkler's characteristics, including the water distribution pattern or spray pattern, the application rate, the wall wetting characteristics, the thermal sensitivity and the temperature rating. These characteristics not only affect the interaction of the sprinklers and a fire but also play a key role in whether the automatic suppression system can control or extinguish the fire. Fire sprinkler application and installation guidelines, and overall fire sprinkler system design guidelines, are provided by the regulations of each country. Fire sprinklers can be automatic or open-orifice. Automatic fire sprinklers operate at a predetermined temperature, utilizing a fusible element (a portion of which melts or a frangible glass bulb containing liquid that breaks) that allows a plug in the orifice to be pushed out of the orifice by the water pressure in the fire sprinkler piping, resulting in the flow of water from the orifice. The water stream impacts a deflector, which produces a specific spray pattern according to the sprinkler type. Most sprinkler heads are designed to direct the spray downwards. Spray nozzles are available to provide a spray in various directions and patterns. The majority of automatic fire sprinklers operate individually in the event of a fire to extinguish the fire.

### 1.4. Sprinkler distribution

The fire safety regulations limit the maximum and minimum distance between two sprinklers. Additionally, there are different limitations according to the specific design of the sprinklers. The reason for limiting the maximum distance between two sprinklers is to prevent any uncovered areas between the sprinklers. The limitation on the minimum distance prevents a sprinkler from being sprayed by an active neighboring sprinkler because getting wet may cause a delay in the activation of that sprinkler.

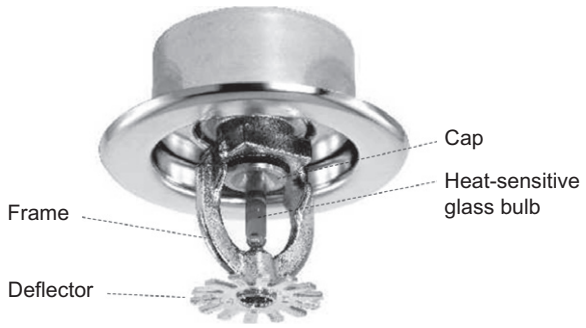


**Fig. 2.** Components of a pendent sprinkler.