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Case study: Flame arresters and exploding gasoline containers

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Abstract

This paper describes the case study of a portable plastic gasoline container explosion and fire. While working at home on a science project to determine the burn rates of different types of wood fuel, a 14-year-old boy was severely burned after flames traveled back up into the portable gasoline container and exploded. A witness heard the explosion and reports that the flames went perhaps 10 ft in the air. It is shown by experimentation that a flame arrester installed in the pour opening of the portable gasoline container would have prevented an explosion inside the gasoline container.
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Keywords: Fire; Explosion; Gasoline; Flame arrester

1. Background

In this incident, a 14-year-old boy was severely burned while working at home on a science project to determine the burn rates of different types of wood fuel. Police investigation revealed that the fire was started by a vapor fumes explosion.

Prior to the fire, the boy dug a pit and put rocks around it. He placed crumpled paper and three different types of wood in the fire pit, and used a cigarette lighter to light the paper. He kept adding paper because the wood had not yet caught fire. He then walked over to his house and picked up a gasoline container. The boy estimated that the 5-gal gasoline container weighed "probably a little more than a gallon of milk." The boy stated that there was "a really small flame" in the fire pit when he went to pick up the gasoline container. He intended to pour gasoline on the wood to help it catch fire. He did not remember anything after he picked up the gasoline container and tilted it toward the pit. The next thing he remembered was waking up on the ground with his legs on fire.

A neighbor across the street heard the explosion, followed immediately by the sound of someone screaming in pain. He saw the boy, on fire from head to toe, running across the yard. The flames went perhaps ten feet in the air. While family members took care of the boy, the neighbor set about extinguishing the fire. He reported some surface fire on the boy's house and on the house next door, which he assumed to be gasoline, and which appeared to be already diminishing. He reported considerable fire in leaves and debris in the area between the houses and against the wall of a shed appended to the house next door. The neighbor stated, "What remained of the plastic gasoline can was near the house and was still dripping gasoline, so I moved it to a more central location, away from the two houses and from any combustible materials."

Fire department units arrived shortly after the incident, and extinguished the burning gasoline can and a small area of burning leaves. The fire department report describes the cause of the incident as: "Accidental flammable ignition of a gas can to exposed flame causing the can to explode splattering the victim with gas and flame." The boy was burned over 65% of his body, and suffered permanent hearing loss in his right ear.

2. Explosion definitions

There are several definitions of an explosion. The dictionary defines an explosion as: (1) bursting noisily, (2) undergoing a rapid chemical or nuclear reaction with the production of noise, heat and violent expansion of gases, and (3) bursting violently as a result of pressure from within.

A more scientific definition is given by Strehlow and Baker: "In general, an explosion is said to have occurred in the atmosphere if energy is released over a sufficiently small time and in a sufficiently small volume so as to generate a pressure wave of finite amplitude traveling away from the source. This energy may have originally been stored in the system in a variety of forms; these include nuclear, chemical, electrical or pressure energy for

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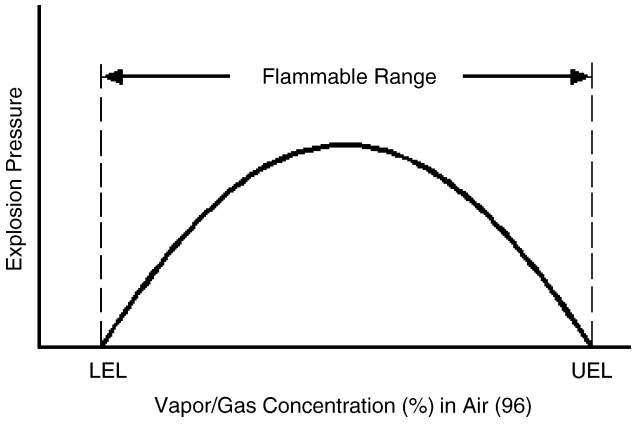

Fig. 1. Flammable range of gasoline.

example. However, the release is not considered to be explosive unless it is rapid enough and concentrated enough to produce a pressure wave that one can hear. Even though many explosions damage their surroundings, it is not necessary that external damage be produced by the explosion. All that is necessary is that the explosion is capable of being heard [1]."

According to NFPA 921: "An explosion is a physical reaction characterized by the presence of four major elements: high pressure gas, confinement or restriction of the pressure, rapid production or release of that pressure, and change or damage to the confining (restricting) structure." An explosion is almost always accompanied by the production of a loud noise. NFPA 921 also gives the following example: "The ignition of a flammable vapor/air mixture within a can, which bursts the can or even only pops off the lid, is an explosion [2]."

For the purposes of this article, an explosion refers to the rapid release of burning gasoline from a gasoline container accompanied by a loud noise.

3. Physical properties of gasoline

Gasoline is a hydrocarbon mixture refined from petroleum. The liquid phase does not burn – only the vapors do. Gasoline has a flash point of −45 °F and an autoignition temperature of 495 °F [3,4]. The molecular weight (and vapor density) of gasoline is about 3.4 times that of air. Thus, gasoline vapors tend to stay near ground level and move around and spread out under the influence of air currents and the confinement of walls.

The explosive range (or flammable range) of gasoline is between 1.4 and 7.6% volume in air [5,6]. Below the lower explosive limit (LEL), there is not a sufficient concentration of vapors in the air to permit propagation of a flame upon contact with an ignition source. Above the upper explosive limit (UEL), there is too great a concentration of vapors in the air to permit propagation of a flame. See Fig. 1.

4. The history of flame arresters

Sir Humphrey Davy developed the first miner's flame safety lamp in 1815 [7]. The Davy lamp focused on a safe way to provide lighting for coal miners, and involved the use of a perforated metal barrier to prevent the propagation of a flame through a flammable vapor mixture. The gauze of the lamp commonly used contains about 26 apertures in the length of 1 in. or 676 in the square.

The principle of the Davy lamp has been utilized in various patent applications over the past two hundred years. The first U.S. patent for a spark arrester was granted to O.S. French and J.W. Miller on June 19, 1906 [8]. The spark-arrester invention was particularly adapted for traction-engines, although applicable to locomotives or stationary engines.

During the early 1930s, R.J. Anschicks, assignor to Protectoseal Company, developed and patented a tank fitting that incorporated a flame arrester [9]. This fitting was used to protect large atmospheric storage tanks in the petroleum and petrochemical industries from fire and explosion. All gasoline containers currently manufactured by the Protectoseal Safety Container Division have perforated metal flash arresters positioned at each container opening.

Currently, flash arresters are usually manufactured from light gauge perforated metal. The thickness of the metal and the size and location of the perforations are carefully chosen to insure that effective protection against flame propagation is achieved. The flash arrester design allows liquids and vapors to pass through (that is, flow through the perforations) but provides a barrier to flame passage if the vapors on one side of the arrester should be ignited. The flash arrester absorbs and dissipates the heat generated by the flame. It insures that the vapors on the protected side of the flash arrester barrier do not reach their ignition temperature [10–12].

In modern industry, the use of flame arresters is diverse. Flame arresters are commonly installed at the fuel tank opening of gasoline- or diesel-powered industrial trucks and equipments, including forklift trucks, tractors, and airport utility vehicles. Flame arresters are also installed on storage tank nozzles or in flammable vapor piping systems or in flare stacks, in chemical, petrochemical, petroleum and pharmaceutical plants where the storage, transfer, and collection of flammable liquids are part of their daily operation.

According to federal requirements regarding boating safety, "Gasoline engines installed in a vessel after April 25, 1940, except outboard motors, must be equipped with an acceptable means of backfire flame control. The device must be suitably attached to the air intake with a flame tight connection and is required to be Coast Guard approved or comply with SAE J-1928 or UL 1111 standards and marked accordingly."

On National Forest lands, spark arresters must be installed on all internal combustion engines such as four-wheelers, motorcycles, and chainsaws, since a properly operating spark arrester prevents accidental wildfires.

One of the most recent applications of the flame arrester is the Flame Guard® Safety System introduced by the American Water Heater Company in 1999 [13]. This technology has been proven to reduce the risk of home fires from flammable vapors coming in contact with a gas water heater's burner or pilot light.

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