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Fire accident investigation of an explosion caused by static electricity in a propylene plant

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ABSTRACT

This study investigated a 2010 fire and explosion that occurred at a polypropylene (PP) and copper-clad laminate high-tech plant in Taiwan. Liquid acetone leakage caused the fire and explosion. One person was killed and five were injured; property damage was estimated at US$20 million. In contrast to conventional plants, high-tech plants have sophisticated instrumentation, highly complex pipelines, and confined spaces. In addition, the floor area in a high-tech plant is large and frequently contains a channel through the ground floor to the second or third floor. This channel design enables the fire compartment to be destroyed. Therefore, the system cannot confine the fire to a specific area, thus hindering fire-relief operations. In this study, the original fire outbreak occurred in the PP processing area on the ground floor. The acetone storage tank was located on the third floor. The investigation conducted at the fire site of the situations of the burning (bursting) loss determined that the acetone liquid leaked and dripped from floor cracks and tunnel oven to the PP processing area. Because the PP manufacturing process rapidly generates static electricity, the flammable liquids made contact with the source of ignition, which caused the explosion and fire. Various procedures, such as those involving the operating environment of production, packaging, and processing in a high-tech plant, are likely to produce static electricity in a workplace. Improved electrostatic management can prevent the loss of property and lives, liquid acetone leakage, and loss of equipment caused by static electricity fire.

1. Introduction

Domestic high-tech industries, including electronics, computer, and biotechnology, have gained recognition in the international market. Numerous high-tech plants have been established in Taiwan, elevating the potential risk of poisonous gas diffusion, fires, and explosions in these plants. Therefore, disaster prevention in high-tech plants has become increasingly crucial (Hsieh, 2014; Li, 2014). This study explored and analyzed fire and explosion cases that involved polypropylene (PP) and copper-clad laminates (CCLs) in high-tech plants in Taiwan in 2010; the incidents were caused by liquid acetone leakage. The space and fire characteristics of high-tech plants were investigated to determine the potential risk of plants by using an analysis of similar spatial features (Suardin et al., 2009; Dana et al., 2014).

1.1. Spatial features of a high-tech plant

(1) Solid and secure structure
The frame of a high-tech plant is composed of steel or reinforced concrete for increasing the load capacity and preventing process failure because of strong winds or seismic shaking. Firefighters should not encounter a building

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collapse when entering this type of plant during a fire outbreak.

(2) Broad floor area
To establish a unique building for convenient operating processes, the office, clean room, work area, and laboratory tend to be consolidated in high-tech plants. This creates a broad space on each floor where fire can easily spread.

(3) Special and complicated decorating materials
Although they appear solid and refractory, interior decorations, furnished items, and materials in a high-tech plant are extremely complex because of extensive usage purposes. During a fire outbreak, the fire burns rapidly, produces high-temperature smoke, and emits high amounts of toxic substances, which can considerably endanger lives.

(4) Dense cover and complex arrangement of various types of pipelines
Because various instruments, chemicals, and machinery within a plant are connected by pipelines that transport flammable and explosive gases or liquids, the leakage that occurs during continuous operation is not easily discovered or immediately managed. In addition, the extension of pipelines in all directions, particularly via sites with a fire compartment that is not effectively filled with non-combustible material, forms a path for smoke and heat.

(5) Special zoning design
Because the processes are primarily conducted in the confined space of a clean room, excluding the dense smoke and heat that gather in a plant is challenging during fire outbreaks. The destruction of zoning to smooth automatic operations frequently causes the rapid spread of fire.

(6) Mechanically intensive configuration and long-term operation
In most high-tech plants, an excessive amount of equipment is allocated to each unit size of plant space for maximizing space utilization. Such equipment is mostly fixed and difficult to move, thus increasing the blind spots in disaster protection and hindering the identification of ignition points and rescue operations.

(7) Heating process
A manufacturing process error can rapidly cause a fire in a high-temperature environment.

1.2. *Fire prevention features of a high-tech plant*

(1) Dense smoke inside the fire ground
Because most materials in a high-tech plant are combustible, they typically produce a considerable amount of smoke during fire outbreaks; the smoke tends to spread to other spaces via various space openings, passages, staircases, and pipelines. These conditions can obstruct sight and rescue operations.

(2) High temperature on the fire ground
Because most high-tech plants contain sealed buildings, the heat generated from interior combustion easily accumulates because it cannot dissipate to the outside. Rapid fire spreading during a fire outbreak: if the interior of a plant is decorated with flammable materials, the fire will rapidly spread and the special space zoning will increase the spreading rate.

(3) Prolonged period of firefighting because of the difficulty in determining or identifying the ignition point: this condition is primarily caused by the broad area and spacious configuration of plants.

(4) Substantial water damage
During a fire-rescue operation, the difficulty in determining or identifying the ignition point and broad space of a plant necessitates pumping a high volume of water into the targeted room to cool the temperature and enable firefighters to approach the ignition point. In this case, the extent of the damage is more substantial compared with a typical fire.

(5) Difficult escape
When dense smoke is generated within a broad area, the complex spatial dynamic line design of a plant hinders the escape of personnel during a fire outbreak.

(6) High quantity of toxic and hazardous materials
Using a high quantity of toxic and dangerous products in plants increases the risks for escaping personnel and firefighters, creating additional challenges in fire-relief operations.

(7) Rescue difficulties because of the destruction of fire compartments
Because most plant processes are designed for automatic operation to reduce manpower, the original fire compartments are frequently destroyed to facilitate the installation of machines and equipment. This not only expands the combustion area but also exacerbates the difficulties of fire-rescue operations.

1.3. *Thermal hazard characteristics of acetone*

Acetone is a flammable liquid that causes slight irritation when it makes contact with human skin; it can be injurious or fatal if swallowed or inhaled. Acetone is typically used as a solvent for chemicals. Chi et al. (2012) performed differential scanning calorimetry analyses by using thermal analysis instruments and vent sizing package 2 for investigating the analytic thermal characteristics of hydrogen peroxide with acetone solvent.

2. Disaster case review

By combining high-tech plant space and fire characteristics, the current study investigated a fire that occurred at a PP and CCL high-tech plant for augmenting the awareness of plant management to prevent similar occurrences effectively.

This fire occurred at 4:00 p.m. on December 10, 2010. The plant site comprised the administration building, Plants 1 and 2, automatic warehousing, raw material warehouse, and outdoor storage tank area. The administration building, Plants 1 and 2 were reinforced concrete structures, whereas the automatic warehousing and raw material warehouse were steel reinforced structures that were specifically employed for producing and manufacturing CCL and PP. This disaster caused one death, injuries to five employees, and a property loss of approximately US$20 million. The cause of the fire and explosion was attributed to the leaking flammable liquid (acetone) that encountered ignition sources (static) (Lin, 2014; Ye, 2014).

The weather was sunny at the time of the fire outbreak. When the fire brigade department arrived at the fire site, they quickly determined that the plant was a steel-reinforced concrete structure and that the plant rear warehousing was a metal structure. The windows and doors were closed and the power supply was shut down. Flames and smoke erupted from