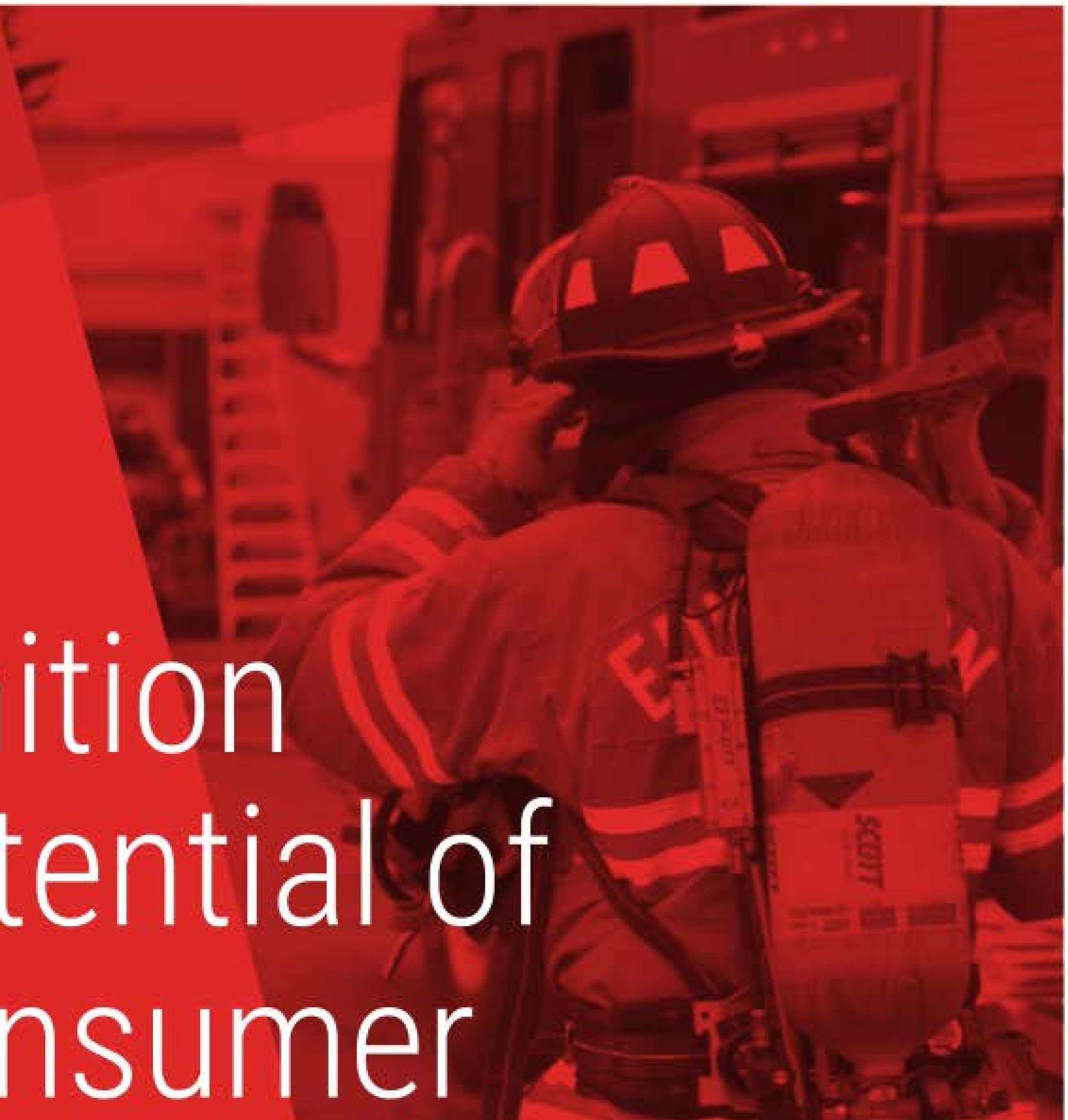

Ignition Potential of Consumer Fireworks

EDMONTON FIRE
RESCUE SERVICE

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1.0 Ignition Potential of Consumer Fireworks

This paper investigates the ignition potential of fireworks specifically classified as Type F.1 Consumer Fireworks under the Canadian acts and regulations.

1.1 EXECUTIVE SUMMARY

Consumer Fireworks have been attributed to causing fires in urban and wildland areas, however there is some ambiguity in terms of the technical ignition potential from these devices. Most data available on instances of fires started by fireworks originates from the United States, which has a different classification and retail availability for some devices. This report examined the relevant classification and characteristics of Consumer Firework in Canada, the technical basis for ignition from these devices within an urban environment like the City of Edmonton, and reviewed empirical evidence where exemplar devices resulted in unintended fire losses. Although statistical information originating from Canada for firework-caused fires was unavailable, care was taken to evaluate and characterize the devices known to have resulted in fires in US case studies, ensuring that those devices were also within the allowable regulated devices in Canada.

This report concludes that latent fires resulting from Consumer Fireworks use are both possible, and in many cases expected, based on their intended operating characteristics. The most likely fuel source for urban fires from fireworks use is biomass material. This is particularly relevant as these fuels are likely to become even more subject to unintended fires as a result of climate change.

1.2 BACKGROUND INFORMATION

The ignition potential of Consumer Fireworks is an important factor in considering policies and regulation for their use within the City of Edmonton. This report outlines the materials, products, and components which constitute Consumer Fireworks, and evaluates whether they are potential sources of unintended ignition within the urban context of the city. Care was taken in this report to only include the context of Consumer Fireworks available in Canada, and the urban factors which can contribute to fire growth. This report did not examine the ignition potential from other regulated explosives, including Display Fireworks and Special Effect Pyrotechnics which are only available to licensed users.

2.0 Methodology

In order to determine the potential for Consumer Fireworks to cause unwanted fires, the relevant acts, regulations, and standards were first reviewed. Classification and characterization of the various categories of fireworks, their allowable chemical compositions, and the combustion characteristics of those compounds was evaluated. Further, the ignition potential of common natural and anthropogenic fuels were reviewed to establish the potential for fireworks causing unintended fires, specifically during display. Intentional ignition sources, such as open-flames required by users to initiate firework devices, were not contemplated here, nor were the risks associated with storage, and transportation of fireworks.

2.1 REGULATORY REFERENCES

The following Acts, regulations, standards, and guidelines were referenced in the preparation of this report:

- Canadian Explosives Act (R.S.C., 1985, c. E-17)
- Canadian Explosives Regulation, 2013 (SOR/2013-211)
- Natural Resources Canada, Classification by Potential Effects (2007)
- Natural Resources Canada, Guidelines for Authorization of Consumer and Display Fireworks (2016)
- Natural Resources Canada, General Standard for the Authorization and Classification of Explosives (2011)

3.0 Findings

This section will outline the classification and characterization of Consumer Fireworks, specifically in relation to their ability to initiate unintended fires from use/demonstration. Next, a summary of potential and common fuels in the urban environment will be identified, and characterized in terms of their ignition propensity from the effects of fireworks. Finally, a review of relevant studies and case histories will be presented to provide empirical evidence of the theoretical ignition scenarios.

3.1 CLASSIFICATION OF CONSUMER FIREWORKS

Fireworks in Canada are separated into three distinct categories/Types, specifically Type F.1 Consumer Fireworks, Type F.2 Display Fireworks, and Type F.3 Special Effect Pyrotechnics. Distribution, sale, and use of Type F.2 and F.3 fireworks are limited to licensed users, however Type F.1 are available for purchase and use without special licensing (i.e., intended for consumers) subject to provincial and municipal restrictions.

In addition to the Type classification, Consumer Fireworks are defined by testing standards based on their category/use-characteristics covered in the NRC Guidelines for the Authorization of Consumer and Display Fireworks. The categories for Consumer Fireworks include Reports (bangs), Cakes, Flares, Combinations (Roman Candles), Wheels, Fountains, Ground Spinners, and Shot Tubes. Each category sets limits for pyrotechnic compositions and black-powder contents, which generally require that no device contains more than 300g total of pyrotechnic material, and 800mg of pyrotechnic material (or 2g of black powder) per effect/report. These limits of explosive material help characterize the combustion effects of these fireworks, as well as their ability to ignite combustible materials.

In addition to the composition and construction of fireworks, the authorization guideline also highlights performance characteristics of the various categories of fireworks. These include effect limits/distances, and mandatory labeling to communicate the effect. Some ground-based examples include:

- **Flares** - Ground-level firework that consists of a thin-walled cylindrical tube into which a pyrotechnic composition is pressed or cast. While burning, the pyrotechnic composition produces a hot bright-coloured flame. The tube may burn away with the composition. These fireworks must include the labeling, “WARNING: EMITS FLAMES.”
- **Fountains** - Ground piece fireworks that are filled with pyrotechnic composition and usually having a choke or restricted orifice. When ignited, it projects a jet or broad spray of fire and sparks. Fountains may contain microstars.
- **Ground Spinners** - Non-metallic tube containing gas and sparks-producing pyrotechnic composition, with or without noise-producing pyrotechnic composition. Rotation on the ground and emission of sparks and/or flames with or without aural effect.
- **Strobe Pots** - Small tubes or end plugs that are pressed, cast or loaded with strobe composition. They generate a blinking effect where bright flashes of light are produced at fairly regular intervals with relatively complete darkness between flashes. Total pyrotechnic composition must be no more than 40g, and devices must be labeled, “WARNING: EMITS FLAMES.”

Examples of aerial fireworks include:

- **Roman Candles** - Cylindrical tubes containing a series of pyrotechnic units (stars, including microstars, small effects) consisting of alternating pyrotechnic composition, propellant charge and transmitting fuse. These may include reports (delayed bangs) up to 800mg of pyrotechnical material, or 2g of black powder. Labeling must state, “WARNING: SHOOTS FLAMING BALLS.”

3.2 MATERIAL COMPOSITION OF CONSUMER FIREWORKS

Consumer Fireworks vary widely in terms of construction and effects, however share some characteristics key to assessing unintentional ignition of combustible materials. The most common feature is tightly rolled paper and tubes, which are subject to both flaming and smouldering combustion in operation. These combustion effects are latent to the effect of the firework, and are evaluated in the Guideline for Authorization generally requiring that sparks and flaming components which are not part of the effect do not project more than 5m from the ignition point. Stated differently, there is an expectation of flaming debris within the proximity of some fireworks which is accepted as part of the operation of Consumer Fireworks.

3.3 URBAN FIRE POTENTIAL

Materials in the urban environment most subject to ignition from pyrotechnic devices like fireworks include materials prone to low-energy ignition, and smouldering combustion. This is commonly biomass debris and decorative material such as dried grasses, leaves, and mulch. These materials are found year-round in Edmonton, and often accumulate around structures, increasing the hazard associated with unintentional fires (i.e., accumulation in basement window-wells, gutters, fence lines, and naturalized areas). Characterizing the ignition potential of these fuels is challenging based on effects such as moisture content of the fuel, as well as weather (i.e., wind). Significant research on the ignition of these materials as a result of wildland urban fire spread has been conducted, and while current studies are focussed on specific scenarios, the research is developing a pattern of empirical relationships between spark, ember, and brand ignition of common fuels, providing qualitative tools to assess ignition potential of biomass from sparks and embers. This mechanism for Wildland Urban Interface fires is an appropriate analogy to the potential for urban fires caused by fireworks.

3.3.1 Particles and Sparks - Smouldering Ignition

Smouldering combustion is that which does not exhibit open flame, and can occur in both low-energy and low-oxygen environments. Consumer Fireworks create many effects which exhibit smouldering combustion both from the intended effects, and debris from product casings and packaging.

Urban biomass like leaves and dry grass is generally prone to smouldering ignition due to the low thermal mass. Known and intentional effects from Consumer Fireworks are very suitable ignition sources for these fuels, particularly in an area about 5m from where fireworks are ignited, as indicated by the classification, authorization and performance requirements indicated for Consumer Fireworks. In addition, pyrotechnic compositions in distant effects like reports/bangs in roman candles are also generally very suitable for igniting biomass under certain conditions.

For example, regulations for Consumer Fireworks permit reports to consist of up to 800mg of pyrotechnic composition, or 2g of black powder. The combustion of black powder results in the release of significant heat energy and temperatures on the order of 1,000°C. While it is technically challenging to evaluate specific ignition potential between the range of ignition sources from fireworks and the range of variables of biomass fuels, the combustion characteristics of consumer fireworks is generally sufficient to ignite dry biomass.

3.3.2 Flaming Ignition

Consumer Fireworks create flaming combustion through intended as well as latent effects such as combustion of packaging and casing debris, generally consisting of paper. These effects are known to occur within up to 5m of the ignition site of some fireworks as allowed by the regulations, but can also occur distant from the ignition site such as with roman candles, which shoot flaming projectiles. Flaming ignition of biomass is more likely to occur compared to smoldering ignition, due to the higher local energy release rate of the ignition source. Mechanisms for continued combustion of the biomass can also include smoldering combustion, which may represent large time-delays from the point of ignition until the fuel displays visible smoke or flaming.

3.4 EMPIRICAL EVIDENCE

While the theoretical information available to conclude the ignition potential of Consumer Fireworks is hard to define based on the extremely broad characteristics of both fireworks and biomass, there is empirical information available to address that uncertainty. The following are specific examples and case studies wherein Consumer Fireworks use resulted in unintended fires, specifically from effects with similar or less pyrotechnic material than permitted in the Canadian regulations, and igniting biomass.

3.4.1 ESI Consultants - Ignition Source Viability: A Firework Story[1]

Engineering Systems Inc. (ESi) completed a study in 2016 which investigated the viability of fireworks as a potential ignition of a structure fire. The study included review of fire and police reports, witness statements, depositions, and photographs. A ladder-sequence of multiple tests was created to demonstrate whether the Black Cat BC401 firework in question was a viable ignition source. Testing indicated the firework samples were subject to erratic travel, and sputtering (discharging sparks before the report). The firework wrapping was also prone to burning, and sufficient to ignite exemplar biomass taken from the site (leaves, pine needles, and cedar shakes). The Black Cat BC401 firework was deemed a viable ignition source. Although this specific firework varies from those regulated in Canada, it is important to note the pyrotechnic composition which forms the suitability as an ignition source. The BC401 was a hand-rolled 50mg report-powered bottle rocket, therefore with pyrotechnic composition far less than similar fireworks in Canada, such as Roman Candles with reports with up to 800mg of pyrotechnic composition, and similar to products like the "Not Bottle Rockets" from Competition Fireworks.

3.4.2 El Dorado Ranch Park Fire[2]

A fire was initiated by a pyrotechnic device at a gender-reveal event at El Dorado Ranch Park in California, United States in 2020. The unidentified pyrotechnic smoke-producing device ignited dry grass adjacent to the device, and despite efforts of those present to extinguish the grass fire with water bottles the fire eventually consumed about 92 square kilometers of land, destroying buildings, and resulting in the death of one firefighter. Litigation of this event is ongoing, and technical details regarding the device are not available. It should be noted however that the ignition of combustibles within 5m of consumer fireworks is permitted through regulations in Canada. There are numerous devices available in Canada such as smoke bombs and fountains which can initiate fires similar to the one at El Dorado Ranch Park through direct and adjacent flame production, and this event indicates the potential for non-intentional ignition of biomass via fireworks.

3.4.3 Eagle Creek Fire[3]

A fire in the Columbia River Gorge in 2017 was initiated by a boy discharging firecrackers into the canyon. The fire resulted in the burning of 50,000 acres of wildland area. While the specific composition of the firecracker which caused the fire was not disclosed, regulations in the US limit ground-devices to 50mg of pyrotechnic

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[1] Engineering Systems Inc, (March 2022) "*Ignition Source Viability: A Firework Story*", https://www.engsys.com/projects/ignition-source-viability-a-firework-story

[2] NPR, (July 2021) "*A Couple Is Charged In A Deadly Fire Sparked By Their Gender Reveal*" https://www.npr.org/2021/07/20/1018622165/a-couple-is-charged-in-a-deadly-fire-sparked-by-their-gender-reveal

[3] NPR (May 2018) "*Judge Orders Boy Who Started Oregon Wildfire To Pay $36 Million In Restitution*" https://tinyurl.com/2cmsxbj7

composition (16 CFR 1500.17(a)(8)), which is consistent with Consumer Fireworks regulations in Canada, wherein reports in devices like roman candles can contain reports with up to 800mg of pyrotechnic composition.

3.5 DISCUSSION

Characterizing the specific mechanisms for firework ignition of urban fuels is complex for a number of reasons. Both fireworks and urban fuels are extremely broad, as are the environmental conditions and controlled/proper use of those devices. However, careful review of the specifications of Consumer Fireworks in Canada, consideration of the combustion effects of typical Consumer Fireworks (total energy, temperature, and propensity for self-ignition of debris) provide clear indication of their potential for igniting biomass such as dried grass, leaves, and other common ground covering. Furthermore, there is sufficient empirical evidence to demonstrate successful and unintended ignition of common biomass fuels from firework devices which fall well within the design specification limits in the Canadian regulations. Further research and study could more discreetly demonstrate the propensity for ignition of biomass from exemplar devices found locally in Edmonton, however the benefit of such work is redundant given the known and even indicated performance characteristics of Consumer Fireworks referenced in the Guidelines for Authorization of Consumer Fireworks (i.e.,"WARNING: SHOOTS FLAMING BALLS").

Biomass was considered in this report to be the most viable material first ignited given its propensity for low-energy ignition without direct flame impingement. As discussed, the properties of biomass materials vary through uncontrolled factors such as accumulation (natural and human-centered), and also by environmental factors like temperature, wind, relative humidity, and precipitation. These factors are also well understood in relation to risks associated with wildfires, which are expected to be more common and more extreme because of climatic changes[4]. Consumer Fireworks contribute to the increasing risk of wildland interface fires, and as biomass fuels become more available through climate change, this risk will increase.

4.0 Conclusion

Consumer Fireworks, as regulated by the Canadian Explosives Act and Regulations, are viable sources of ignition, and pose specific fire safety risks towards typical biomass fuels found in the urban and wildland urban interface areas. There is sufficient evidence to support the likelihood of Type F.1 Consumer Fireworks use initiating unintentional fires, which can have significant social consequences.

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[4] Mike Flanigan, *"Fire and Climate Change"*, University of Alberta, https://sites.ualberta.ca/~flanniga/climatechange.html