RESEARCH TECHNICAL REPORT

Expanded Fire Protection Recommendations for Plastic Aerosol Containers for Incorporation into NFPA 30B

FM Global

Expanded Fire Protection Recommendations for Plastic Aerosol Containers for Incorporation into NFPA 30B

Prepared by

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NFPA 30B Code for the Manufacture and Storage of Aerosol Products

PROJECT ID RW000225

Disclaimer

Executive Summary

To support the continued development of plastic aerosol products, and their required protection, FM Global conducted testing on several new product variables of plastic aerosol containers. The goal of the testing was to screen these new formulations and either categorize them into the existing definition for Plastic Aerosol 3 or define new product categories for the variables. The results of the program identified two products to classify as Plastic Aerosol 3, two products to classify as a new product category Plastic Aerosol 2, and two products to classify as a new product category Plastic Aerosol Cooking Sprays. These new product classifications and categories are proposed for acceptance into NFPA 30B, Code for the Manufacture and Storage of Aerosol Products and FM Global Property Loss Prevention Data Sheet 7-31, Storage of Aerosol Products. The definition of each product is summarized in the Summary Table below.

Summary Table: New Plastic Aerosol Products

Product Definition	**Product**	**Propellant***	**Container Style**
Plastic Aerosol 2 Products	20% to 50% v/v, water miscible alcohol in water	Non-flammable propellant	Direct fill
	20% to 50% v/v, water miscible alcohol in water	Non-flammable propellant	Bag-on-valve
Plastic Aerosol 3 Products	51% to 100% v/v, water miscible alcohol in water	Non-flammable propellant	Bag-on-valve
	Non-flammable aqueous base product	≤10% (by weight) emulsified flammable propellant+	Direct fill
Plastic Aerosol Cooking Spray Products	Cooking spray with closed cup flash point ≥212 °C (414 °F) with ≤10% v/v ethyl alcohol	Non-flammable propellant	Direct fill
	Cooking spray with closed cup flash point ≥212 °C (414 °F) with ≤10% v/v ethyl alcohol	Non-flammable propellant	Bag-on-valve

*Non-flammable propellants tested were nitrogen and HFO-1234ze.
+Flammable propellant tested was A-46.

Abstract

To support the continued development of plastic aerosol products, and their required protection, FM Global conducted testing on several new product variables of plastic aerosol containers. The goal of the testing was to screen these new formulations and either categorize them into the existing definition for Plastic Aerosol 3 or define new product categories for the variables. The results of the program identified two products to classify as Plastic Aerosol 3, two products to classify as a new product category Plastic Aerosol 2, and two products to classify as a new product category Plastic Aerosol Cooking Sprays. These new product classifications and categories are proposed for acceptance into NFPA 30B, Code for the Manufacture and Storage of Aerosol Products [1] and FM Global Property Loss Prevention Data Sheet 7-31, Storage of Aerosol Products [2].

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1. Introduction

To support the continued development of plastic aerosol products, and their required protection, FM Global conducted testing on several new product variables of plastic aerosol containers. The goal of the testing was to screen these new formulations and either categorize them into the existing definitions for Plastic Aerosol 3 or define new product categories for the variables. The results of the program identified two products to classify as Plastic Aerosol 3, two products to classify as a new product category Plastic Aerosol 2, and two products to classify as a new product category Plastic Aerosol Cooking Sprays. These new product classifications and categories are proposed for acceptance into NFPA 30B, Code for the Manufacture and Storage of Aerosol Products [1] and FM Global Property Loss Prevention Data Sheet 7-31, Storage of Aerosol Products [2]. The definition of each product is summarized in Table 1-1.

Table 1-1: New Plastic Aerosol Products

Product Definition	**Product**	**Propellant***	**Container Style**
Plastic Aerosol 2 Products	20% to 50% v/v, water miscible alcohol in water	Non-flammable propellant	Direct fill
	20% to 50% v/v, water miscible alcohol in water	Non-flammable propellant	Bag-on-valve
Plastic Aerosol 3 Products	51% to 100% v/v, water miscible alcohol in water	Non-flammable propellant	Bag-on-valve
	Non-flammable aqueous base product	≤10% (by weight) emulsified flammable propellant+	Direct fill
Plastic Aerosol Cooking Spray Products	Cooking spray with closed cup flash point ≥212 °C (414 °F) with ≤10% v/v ethyl alcohol	Non-flammable propellant	Direct fill
	Cooking spray with closed cup flash point ≥212 °C (414 °F) with ≤10% v/v ethyl alcohol	Non-flammable propellant	Bag-on-valve

*Non-flammable propellants tested were nitrogen and HFO-1234ze.
+Flammable propellant tested was A-46.

The first method to assess the hazard of a plastic aerosol product was the single-can test. The test used a single aerosol container suspended above a propane burner within a wire cage. The entire test setup was placed beneath a fire products collector (calorimeter) to measure the products of combustion. A full description of the test setup and calculation of the single-can index is provided in Appendix A.

The second method to assess the hazard of a plastic aerosol product was the two-carton test. The test provides a qualitative assessment of multiple aerosol containers involved in a fire. Two cartons are placed within a cage, separated by 7.6 cm (3 in.) and ignited with an FM Global standard half-igniter. Visual observations are made on the failure rate of the individual containers and the fireball generated. Calorimetry measurements are also collected to analyze the peak energy released during the ruptures. A full description of the two-carton test is provided in Appendix B.

Finally, for one product formulation, an ease of ignition test was conducted on the base product. The ease of ignition test determines if a liquid will burn when in a larger, open dish. The product is placed in a shallow aluminum dish and subjected to a Meker Burner ignition flame. The product was slowly heated until the product ignites from the exposure flame.

2. **Plastic Aerosol 2 Products**

2.1 Plastic Aerosol 2 Product Description

2.1.1 50% Ethanol, nitrogen propellant, direct-fill container

This product was represented by a 50% ethanol base product, pressurized with nitrogen, in a direct-fill container. Results from the testing can be extended to other non-flammable propellants and to bag-on-valve style containers.

2.2 Plastic Aerosol 2 Testing and Results

2.2.1 Single-can Testing

Three tests were conducted with the representative product described in Section 2.1.1. Upon rupture, a small quantity of the product ejected burning away from the apparatus. Small flames were present until the fuel flow to the propane burner was shut off. Small residual flames were present below the apparatus until the test was terminated. A photo from a single-can test, at the time of rupture, is provided in Figure 2-1.

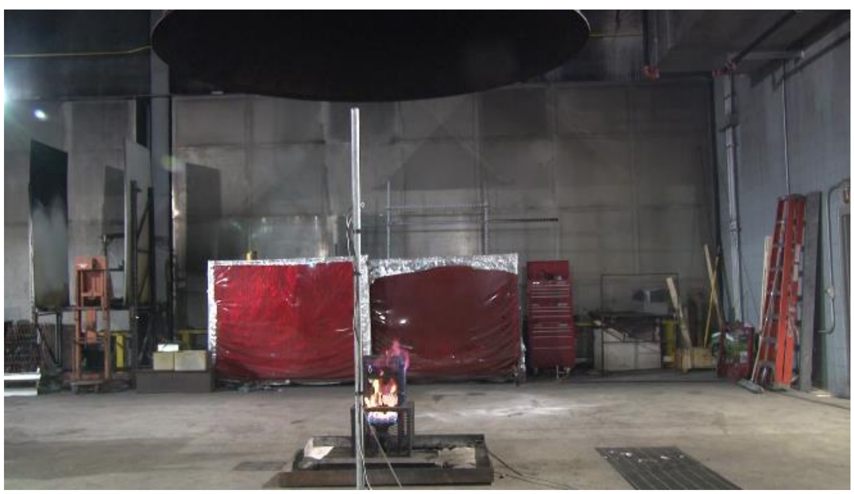

Figure 2-1: Single-can test photo of 50% ethanol base product, non-flammable propellant in a direct fill container.

2.2.2 Two-carton Testing

A single two carton test was conducted with the representative product described in Section 2.1.1. Upon ignition, the corrugated box began to burn. At 45 s, the first container ruptured and all of the containers ruptured by 1 min 40 s. During the test, both single ruptures were observed with several seconds between ruptures, and multiple ruptures within 1 second. On average, the 16 containers ruptured over 55 seconds, or approximately one every 3.4 seconds. None of the ruptures created fire balls and no product was observed burning away from the cartons. A photo from the two-carton test is provided in Figure 2-2.

Figure 2-2: Two-carton test photo of 50% ethanol base product, non-flammable propellant in a direct fill container.

2.2.3 Product Hazard Analysis

During the single-can tests, a small quantity of burning product was ejected away from the apparatus and small flames were present until the fuel flow to the burner was shut off. During the two-carton test, no fire balls were produced as the containers ruptured and no product was observed burning away from the cartons. In a rack-storage arrangement, it is expected that the containers near ignition will rupture, likely above the liquid level in the container at the headspace. This rupture will vent the non-flammable propellant. Once vented, the base product will burn like a 50% water-miscible ignitable liquid in a plastic container. Note, the container size for the plastic aerosol product was 800 mL (27 fl. oz.).

2.3 Recommended Protection of Plastic Aerosol 2 Products

The recommendation is to define a new product, Plastic Aerosol 2, which has a base product of not more than 50% by volume of a flammable, water-miscible alcohol in an aqueous base, with a non-flammable propellant. The recommended protection for rack storage of Plastic Aerosol 2 is equivalent to the existing protection for rack storage of Level 3 aerosols in metal containers.

The protection for cartoned Level 3 aerosols is provided in Table 2.4.2.5 of Data Sheet 7-31 [2]. The recommended protection is also consistent with FM Global Property Loss Prevention Data Sheet 7-29, Ignitable Liquid Storage in Portable Containers [3] for Group 3 (up to 50% by volume) water-miscible alcohol in ≤4 L (1 gal) containers (Data Sheet 7-29, Table 2.4.7.3.1).

3. Plastic Aerosol 3 Products

3.1 Plastic Aerosol 3 Product Description

3.1.1 100% Ethanol, Non-flammable Propellant, Direct-fill Container

This product was represented by three different 100% ethanol base products, pressurized with non-flammable propellants. The first was 100% ethanol, pressurized with nitrogen, in a direct-fill container. The second was 100% ethanol, pressurized with nitrogen, in a bag-on-valve container. The third was 100% ethanol, pressurized with HFO-1234ze propellant, in a bag-on-valve container. Results from the testing can be extended to other non-flammable propellants and to bag-on-valve style containers.

3.1.2 Non-flammable Emulsion, Flammable Gas Propellant, Direct-fill Container

This product was represented by a non-flammable aqueous base product, with 7% by weight of an emulsified, liquified flammable gas propellant (A-46), in a direct-fill container.

3.2 Plastic Aerosol 3 Testing and Results

3.2.1 Single-can Testing

Three tests were conducted with each of the products described in Sections 3.1.1 and 3.1.2. For the 100% ethanol base product with a non-flammable propellant, large fire balls were produced when the plastic aerosol containers ruptured. Ethanol that spilled straight down produced pool fires that were sustained for the duration of the test. Additionally, container ruptures were observed that ejected product away from the test setup and burned on the lab floor away from the apparatus. Photos at the time of rupture during the single-can test, from each of the products tested, are provided in Figures 3-1, 3-2, and 3-3.

For the non-flammable emulsion with a flammable gas propellant, large fire balls were produced upon rupture and the emulsion product was dispersed into the air but was not burning. The product was white in color and could be seen floating in the air and depositing on surrounding surfaces. Very small fires were present around the test apparatus, but the product stopped burning when the fuel flow to the propane burner was shut off. A photo from a single-can test, at the time of rupture, is provided in Figure 3-4.

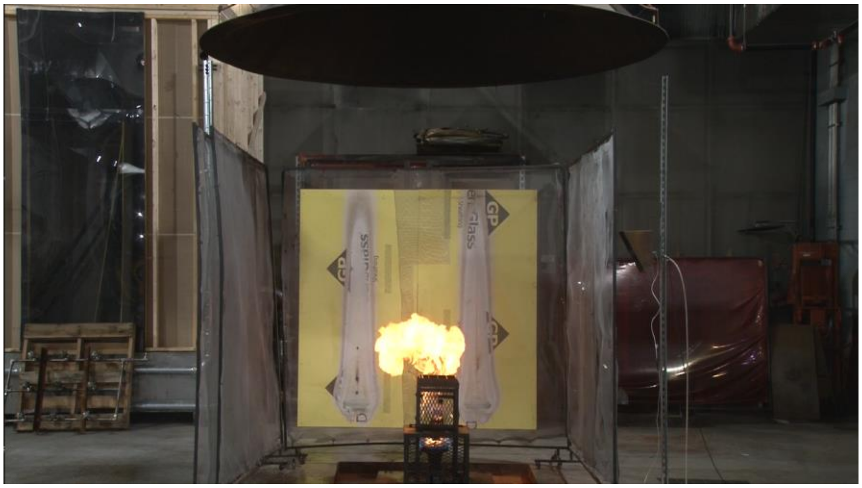

Figure 3-1: Single-can test photo of 100% ethanol base product, non-flammable propellant in a direct-fill container.

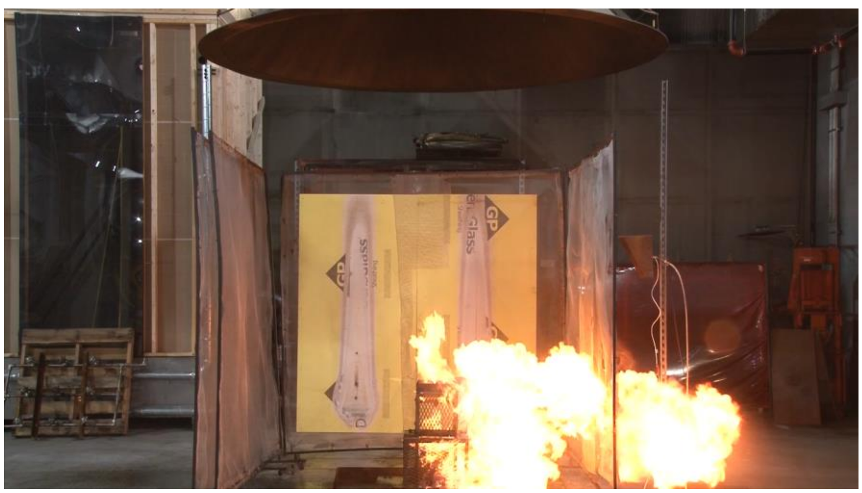

Figure 3-2: Single-can test photo of 100% ethanol base product, non-flammable (N_2) propellant in a bag-on-valve container.

Figure 3-3: Single-can test photo of 100% ethanol base product, non-flammable (HFO-1234ze) propellant in a bag-on-valve container.

Figure 3-4: Single-can test photo of non-flammable aqueous base product, 7% hydrocarbon propellant, direct-fill container.

3.2.2 Two-carton Test Results

A two-carton test was conducted with each of the products described in Sections 3.1.1 and 3.1.2. During the tests with 100% ethanol base product, the initial ruptures produced small fire balls and released liquid that pooled at floor level. As more containers ruptured, they contributed to the pool fire throughout the test. In some instances, ruptures produced large fire balls and discharged burning liquid beyond the test setup. Photos from the 100% ethanol base product are provided in Figures 3-5, 3-6, and 3-7.

During the two-carton test with a non-flammable aqueous base product and 7% hydrocarbon propellant, the initial ruptures produced large fire balls, but no product was observed burning in the containment pan or around the test setup. Subsequent ruptures also produced large fire balls and the emulsion product was discharged as a white foam-looking cloud that slowly floated to the ground. A photo from the non-flammable aqueous base product and 7% hydrocarbon propellant two-carton test is provided in Figure 3-8.

Figure 3-5: Two-carton test photo of 100% ethanol base product, non-flammable propellant in a direct-fill container.

Figure 3-6: Two-carton test photo of 100% ethanol base product, non-flammable (N_2) propellant in a bag-on-valve container.

Figure 3-7: Two-carton test photo of 100% ethanol base product, non-flammable (HFO-1234ze) propellant in a bag-on-valve container.

Figure 3-8: Two-carton test photo of non-flammable aqueous base product, 7% hydrocarbon propellant, direct-fill container.

3.2.3 Product Hazard Analysis

The primary hazard observed during the single-can and two-carton tests was consistent over all three 100% ethanol base products with non-flammable propellants. Ruptures of the plastic aerosol container produced fire balls and ejected the product at the point of failure, which then burned on the floor away from the test apparatus. Additionally, liquid released from the failed container also spilled to floor level and created a pool fire.

The primary hazard of the non-flammable aqueous base product and 7% hydrocarbon propellant was the production of very large fire balls as the plastic aerosol container ruptured. The fire balls extended far enough away from the fire origin to reach across a typical 2.4 (8 ft) aisle.

3.3 Recommended Protection of Plastic Aerosol 3 Products

The recommended protection for plastic aerosol containers with a base product of 100% ethanol and a non-flammable propellant is the current protection for Plastic Aerosol 3 (PA3) in Data Sheet 7-31 [2]. This protection was established through large-scale fire testing of PA3 products in 2018 [4]. Plastic Aerosol 3 is currently defined as a base liquid product that contains not more than 50% by volume of a flammable, water-miscible alcohol, with no more than 10% flammable propellant. This recommendation would extend that definition to include a base liquid product that contains up to 100% by volume of a flammable, water-miscible alcohol, with a non-flammable propellant.

The protection for Plastic Aerosol 3 is provided in Table 2.4.3.3 of Data Sheet 7-31 [2]. The protection is specified as Scheme A for both the ceiling and in-rack sprinklers. The recommended protection is also consistent with Data Sheet 7-29 [3] for Group 1 (up to 100% by volume) water-miscible alcohol in ≤4 L (1 gal) containers.

4. **Plastic Aerosol Cooking Spray Products**

4.1 Plastic Aerosol Cooking Spray Product Description

4.1.1 EVOO, Flash Point ≥ 212 ^{o}C (414 ^{o}F), non-flammable propellant, bag-on-valve container

This product was represented by a base product of extra virgin olive oil [flashpoint ≥ 212 ^{o}C [414 ^{o}F]), pressurized with HFO1234ze propellant, in a bag-on-valve container. Results from the testing can be extended to other non-flammable propellants and to direct-fill style containers. The results can also be extended to permit up to 10% ethyl alcohol mixed with the base liquid product.

4.2 Plastic Aerosol Cooking Spray Testing and Results

4.2.1 Single-can Testing

Three tests were conducted with the product described in Section 4.1.1. Upon rupture, there was no significant fire ball and there was minimal product involvement around the apparatus. The product did continue to burn near the base of the bottle once the flow of fuel was shut off to the burner, and the burning persisted until test termination. A photo at the time of rupture during the single-can test is provided in Figure 4-1.

Figure 4-1: Single-can test photo of extra virgin olive oil, non-flammable (HFO1234ze) propellant in a bag-on-valve container.

4.2.2 Two-carton Testing

A two-carton test was conducted with the extra virgin olive oil (flash point ≥ 212 °C [414 °F]), pressurized with HFO1234ze propellant in a bag-on-valve container product. At each container rupture, no fire ball was produced, but the oil immediately spilled into the containment pan[i]. The fire never grew significantly in intensity and the product was almost completely consumed at test termination. A photo from the two-carton test is provided in Figure 4-2.

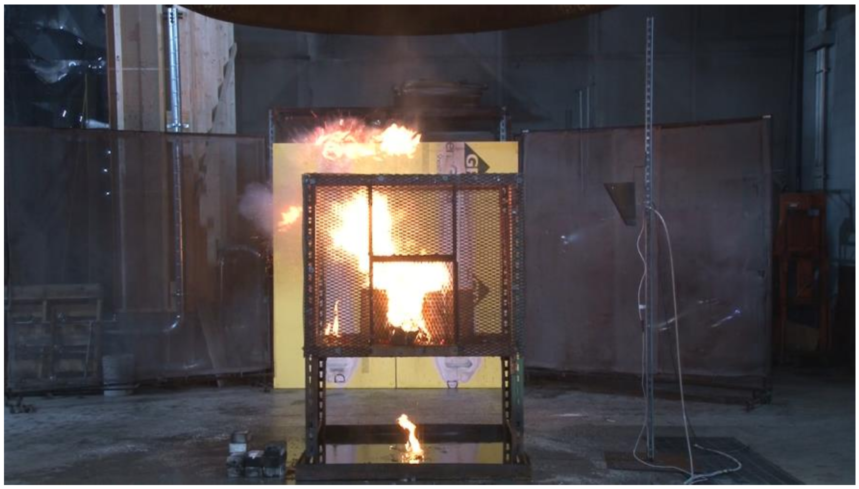

Figure 4-2: Two-carton test photo of extra virgin olive oil, non-flammable (HFO1234ze) propellant in a bag-on-valve container.

4.2.3 Ease of Ignition Test

One additional set of tests was conducted with a cooking spray product as described in Section 4.1.1 with 10% ethyl alcohol mixed into the base product. This combination represents typical commercially available cooking spray products.

The ease of ignition test determines if a liquid will burn when in a larger, open dish. The product is placed in a shallow aluminum dish and subjected to a Meker Burner ignition flame. The product is slowly heated until the product ignites from an exposure flame. This test was selected to identify if the presence of up to 10% ethyl alcohol changed the burning behavior of the base product.

During heating, the ethyl alcohol quickly flashed off, but did not sustain combustion of the liquid pool. The remaining base product did not ignite and sustain combustion until the product reached the flash point of the extra virgin olive oil.

[i] The fire present in the containment pan in Figure 4-2 is unabsorbed gasoline that was used in the standard ignitor. The gasoline spilled out of the bag upon ignition and formed a small pool fire. The fire in the containment pan was not attributed to the extra virgin olive oil.

4.2.4 Product Hazard Analysis

Both the single-can and two-carton test demonstrated that the hazard posed by the extra virgin olive oil base product was minimal. No significant fire balls were observed and there was minimal product involvement for the duration of the tests.

The ease of ignition tests demonstrated that the addition of up to 10% ethyl alcohol did not change the ignition propensity of the base oil content. If involved in a fire, the ethyl alcohol would quickly flash off, leaving the base liquid product as a high flash point liquid. The contribution of ethyl alcohol does not change the fire hazard of the product

4.3 Recommended Protection of Plastic Aerosol Cooking Spray Products

The recommended protection for extra virgin olive oil in a plastic aerosol container is to treat the product equivalent to an aerosol cooking spray product in metal containers. Test data do not suggest that the hazard is significantly different based on the use of a metal container or plastic container. This recommendation would extend the definition of aerosol cooking sprays to include those in plastic containers and to cooking spray products with ≤10% v/v ethyl alcohol. The protection for cartoned aerosol cooking spray products is provided in Table 11 of Data Sheet 7-31 [2].

References

1. National Fire Protection Association, "Code of the Manufacture and Storage of Aerosol Products," NFPA 30B, 2019.

2. FM Global, "FM Global Property Loss Prevention Data Sheet 7-31, Storage of Aerosol Products," Data Sheet 7-31, January 2016 (Interim Revision February 2020).

3. FM Global, "Property Loss Prevention Data Sheet 7-29, Ignitable Liquid Storage in Portable Containers," Data Sheet 7-29, October 2020 (Interim Revision January 2021).

4. J. LeBlanc, S. Sienkiewicz, "Fire Protection Scheme A for Cartoned Plastic Aerosol 3 Products and Level 2 and 3 Aerosol Products," FM Global, Technical Report for NFPA 30B January 2018.

5. Society of Fire Protection Engineers, "The SFPE Handbook of Fire Protection Engineering," National Fire Protection Association, Quincy, MA, 5th Edition, 2016.

Appendix A. Single-can Testing

A.1 Single-can Test Setup

The first method to assess the hazard of a plastic aerosol product was the single-can test. The test used a single aerosol container suspended above a propane burner within a wire cage. The entire test setup was placed beneath a fire products collector (calorimeter) to measure the products of combustion. A photo of the test setup is provided in Figures A-1 and A-2.

Figure A-1: Photo of the single-can test apparatus.

Figure A-2: Photo of test apparatus beneath calorimeter.

The discport-style propane burner was positioned approximately 8.9 cm (3.5 in.) below the aerosol container. The flow of propane to the burner was measured using a volumetric flow meter and the total energy contributed by the exposure source was estimated using the propane heat of combustion (ΔH_c)

of 46.3 kJ/g [5] and was verified via calorimetry during pre-program calibration tests. At the start of each test, the propane burner was lit, providing a steady state exposure fire of 14 kW.

The test was run until approximately 60 seconds after the container ruptured. The exposure fire was kept on for 30 seconds after the container ruptured. At 30 seconds after rupture, the propane flow to the burner was shut off and the test continued for an additional 30 seconds to allow for any residual material to burn. One minute after rupture, a hose stream was applied to the apparatus to terminate the test. Data were collected for an additional 1 minute after termination.

A.1.1 *Determination of Single-can Index*

The single-can index (SCI) for each sample is based on the time to rupture, the energy released from the product, and the total volume of the container. The calculation for SCI is provided in Equation A-1.

$$SCI = \frac{Energy\ Released\ (kJ)}{Container\ Volume\ (cm^3)\ x\ \sqrt{rupture}\ time\ (s^{1/2})} \qquad \text{A-1}$$

The energy released is obtained via calorimetry from gas samples measured in a fire products collector. The primary gases measured are carbon monoxide (CO) and carbon dioxide (CO_2) which are the main byproducts of combustion. By using the heat of formation for both gases, the heat release rate of the burning product can be calculated. By integrating below the heat release rate (HRR) curve during the entire test, the total energy released is determined. The calorimetry data from the test also include the contribution of the propane burner. To account for this energy contribution, the HRR of the propane burner is subtracted from the total energy measured.

The container volume for all tests in this program was the same: 800 mL (27 oz.).

The time to rupture was audibly and visually determined during each test. The container rupture was evident from the sound of the venting gas and increase in fire intensity (above the nominal baseline of the exposure burner flame). Also, for bag-on-valve samples, two rupture times were recorded. First, the time to bottle failure and, second, the time when the bag failed and product contributed to the fire severity. For the calculation of the SCI, the time to failure of the bag was used, since contribution of the product would drive the energy released.

The single-can index (SCI) was originally developed in the mid-1980s as part of a suite of tests to determine the fire hazard of metal aerosol containers. While it was developed for metal aerosol containers, no inference can be made between plastic aerosol and metal aerosol containers and they cannot be compared directly, nor can SCI results be used to establish ceiling sprinkler protection for either style container.

A.1.2 *Sample Calculation of Single-can Index*

A sample calculation of the single-can index (SCI) is provided below for a select test.

Test 4 of the series was conducted with a non-flammable aqueous-based emulsion with 7% by weight A46 hydrocarbon propellant. Prior to ignition, the propane flow was initiated and the test was started upon ignition. At 11 s the container ruptured creating a large fire ball (see Figure A-3). The energy profile for the test is provided in Figure A-3.

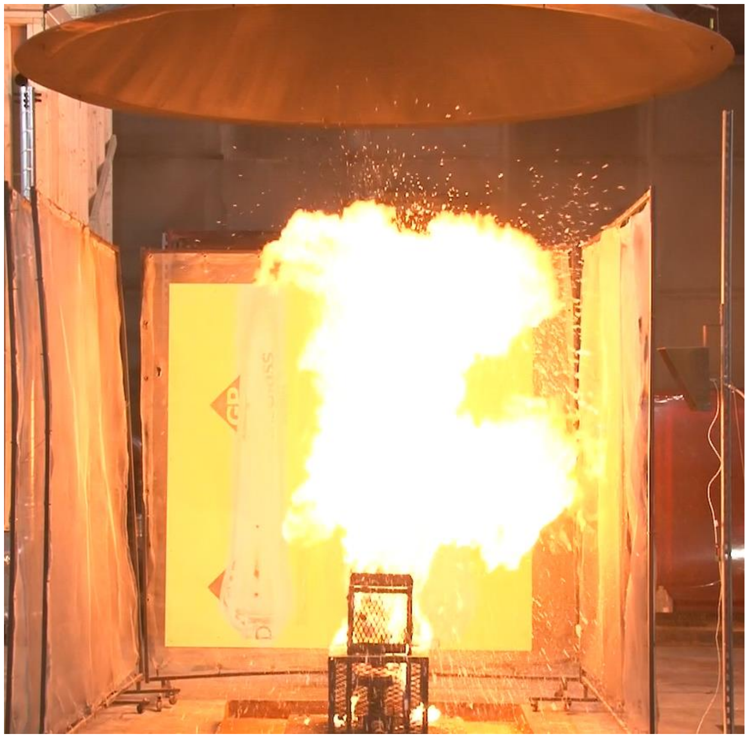

Figure A-3: Photo at time of rupture (13 s) in Test 4.

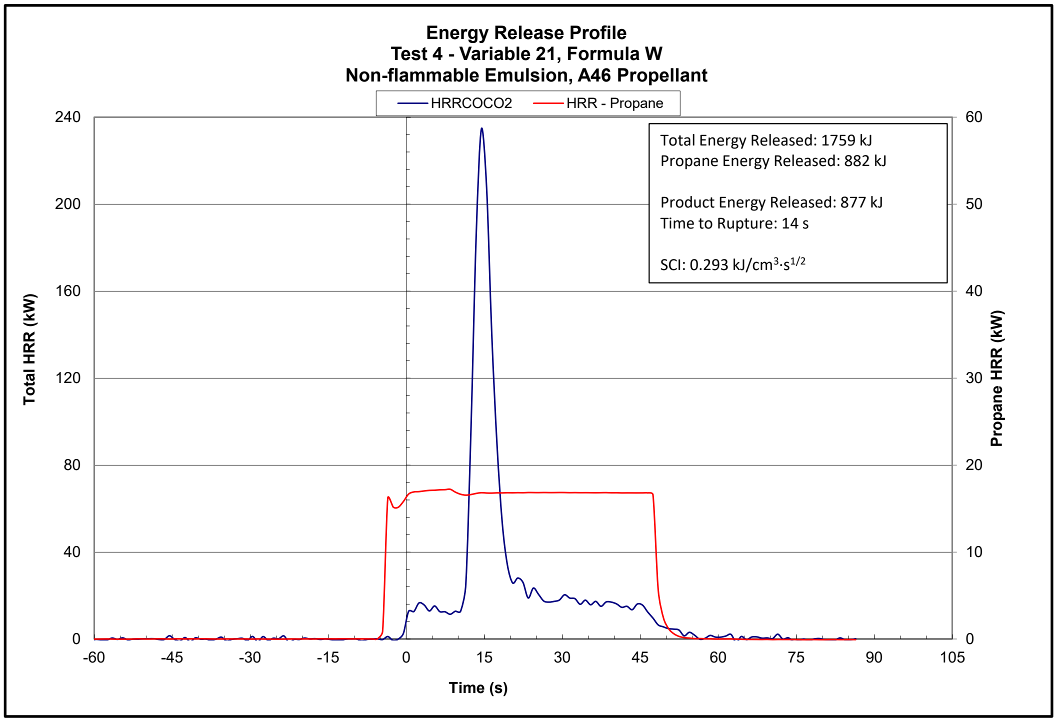

Figure A-4: Energy release profile for Test 4.

The total energy released during the test (integrating under the Total HRR curve) was 1,759 kJ. The total energy released by the propane was 882 kJ. The difference between the two values, 877 kJ was the energy released by the product. Using this energy value, the time to rupture of 14 s, and the container volume of 800 cm^3, the SCI of the aerosol sample can be calculated using Equation A-2.

$$SCI = \frac{877\ kJ}{800\ cm^3\ x\ \sqrt{14\ s}} = 0.29\ \frac{kJ}{cm^3 \cdot s^{1/2}} \qquad \text{A-2}$$

Appendix B. Two-carton Test Setup

B.1 Two-carton Testing

To provide a qualitative assessment of multiple aerosol containers involved in a fire, two-carton tests were conducted on each product formulation. Each carton was approximately 32.4 cm x 16.5 cm x 27.4 cm-high (12.75 in. x 6.5 in. x 10.8 in.-high) and held 8 aerosol containers. The cartons were placed on blocks to elevate them from the floor and an igniter was placed on the floor, below the bottom edge of the cartons. The igniter was an FM Global standard half-igniter, which is a 7.6 cm x 7.6 cm (3 in. x 3 in.) cellucotton roll soaked in 118 mL (4 oz.) of gasoline. The cartons were separated by 7.6 cm (3 in.) and backed by blocks to prevent the cartons from dislodging during the test from container rupture. A photo of the carton placement is provided in Figure B-1.

Figure B-1: Photo of the two-carton test setup.

The two-carton test setup was placed within a safety cage to contain rocketing cans. A photo of the safety cage is provided in Figure B-. During the test, visual observations were made on the failure rate of the individual containers and the fireball generated. Calorimetry measurements were also collected to analyze the peak energy released during the ruptures. The test was allowed to run to completion, which was defined as the time when all of the aerosol containers had ruptured, and the majority of product had been consumed.

Figure B-2: Photo of two-carton test safety cage.

fmglobal.com/research-and-resources/standards-and-certification/code-support-reports