The Fire Safety Hazard of the Use of Flameless Ration Heaters Onboard Commercial Aircraft

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16. Abstract

While it is well established that the shipment of a large quantity of flameless ration heaters poses a significant fire safety risk, this report examines the potential hazard associated with the use of these flameless ration heaters in an aircraft cabin and with the accidental activation of them in a confined area aboard an aircraft, such as in overhead storage bins or a cargo compartment.

Tests were performed both with individual Meals, Ready-to-Eat containing flameless heaters in an open environment and multiple Meals, Ready-to-Eat in a confined space to examine their potential hazard. Temperatures in excess of 215°F and violent ignition events were observed. It is evident from the tests performed that the release of hydrogen gas from these flameless ration heaters is of a sufficient quantity to pose a potential hazard on board a passenger aircraft.

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LIST OF ACRONYMS

FRH	Flameless ration heaters
MRE	Meal, Ready-to-Eat

EXECUTIVE SUMMARY

Flameless ration heaters are devices used for the flameless heating of a meal known as Meals, Ready-to-Eat. The technology behind flameless ration heaters is based on a combination of food grade iron and magnesium. When salt water is added to the iron-magnesium combination, the mixture results in an exothermic reaction, reaching temperatures of up to 100°F in a relatively short amount of time. This rapid rise in temperature is then used to cook the Meal, Ready-to-Eat. Meals, Ready-to-Eat are used extensively in the military as a method of providing meals to soldiers while in the field. They are also finding their way into use by others, such as campers, boaters, and disaster response teams.

While it is well established that the shipment of a large quantity of these flameless heaters poses a significant fire safety risk, this report examines the potential hazard associated with the use of these Meals, Ready-to-Eat in an aircraft cabin, or the accidental activation of flameless ration heaters in a confined area aboard the aircraft, such as in overhead storage bins or a cargo compartment.

INTRODUCTION

Flameless ration heaters (FRH) are devices used for the flameless cooking of a self-heating meal known as a Meal, Ready-to-Eat (MRE). The technology behind FRH is based on a combination of food grade iron and magnesium. When salt water is added to the iron-magnesium combination, the mixture results in an exothermic reaction, reaching temperatures of up to 100°F in a relatively short amount of time. This rapid rise in temperature is then used to cook the MRE. MREs are used extensively in the military as a method of providing meals to soldiers in the field. FRH MREs are also finding their way into use by others, such as campers, boaters, and disaster response teams.

FRH MREs are well known to pose certain fire, explosion, and health-related safety issues while in shipment where typically hundreds of these meals are packaged together in a single shipping container. They are also considered to be a hazardous material under the United Nations publication “Recommendations on the Transport of Dangerous Goods” and in that publication are listed as “dangerous when wet.” The 2004 Emergency Response Guidebook published by the United States Department of Transportation covers FRHs under guide 138: “Substances—Water-Reactive (Emitting Flammable Gases)” and lists the potential fire and/or explosion hazards. Some of the hazards listed include:

- Produces flammable gases on contact with water
- May ignite on contact with water or moist air
- Some react vigorously or explosively on contact with water
- May be ignited by heat, sparks, or flames
- May reignite after fire is extinguished

In fact, a major product of the reaction of the salt water and iron-magnesium mixture is hydrogen gas. The release of hydrogen is the primary cause of any fire safety concern surrounding FRHs and has resulted in at least one cargo fire during shipment. In March 2001, a container filled with FRHs was loaded onto a container ship at a naval station in Guam. The ship’s crew detected leaking hydrogen from the container and removed it from the ship. Fire fighters decided to attempt to move the contents and spread them among three separate containers. While performing this operation, the contents burst into flames as can be seen in figure 1.

While it is well established that the shipment of a large quantity of these flameless heaters poses a significant fire safety risk, this report examines the potential hazard associated with the use of these MREs in an aircraft cabin, or the accidental activation of FRHs in a confined area aboard an aircraft, such as in overhead storage bins or a cargo compartment.

FIGURE 1. RESULTS OF A CARGO FIRE OCCURRING DURING THE SHIPMENT OF MREs IN MARCH OF 2001 [1]

PACKAGING AND USE OF MEALS, READY-TO-EAT

For the purposes of these experiments, several MREs manufactured by La Briute were acquired. The La Briute MREs use an FRH manufactured by ZestoTherm, Inc. Along with the meal itself, the MRE comes packaged with a Styrofoam™ tray, an FRH packet consisting of the iron-magnesium mixture, and a 2-ounce salt water packet. Photographs of these contents and of the MRE packaging are shown in figure 2. The packaging contains a caution not to use the MRE near fire or flame and that the activated FRH will produce heat and steam. No other fire safety warnings are noted on the package. The following are the directions supplied with the MREs:

1. Open carton at side with tab. Save carton. Remove cutlery pack and sodium water pouch. Keep food heater in foam tray. Use on flat, heat-safe surface.

2. Open sodium water pouch at notch. Lift entrée. Pour all water on food heater. Water activates food heater. Replace meal, film cover down on food heater in foam tray.

3. Slide foam tray back into carton. Close carton with tab. After 14 minutes, meal is hot and ready to eat. Slowly remove meal film cover. Stir contents.

FIGURE 2. CONTENTS OF MRE USED IN TESTING

DESCRIPTION OF EXPERIMENTS

INDIVIDUAL MRE TESTS.

Initial tests were performed with individual MREs under varying conditions. Temperatures within the MRE box were taken with a standard K-type thermocouple attached to a digital multimeter. The MRE was activated as specified in the directions in an attempt to determine the maximum temperature occurring within the box as well as the typical temperature rise seen under normal operating conditions. In addition, tests were performed in which the FRH was activated and the MRE container was surrounded by shredded paper to determine if the heat generated had the potential to ignite the surrounding paper. Also, a small flame was held to the vapors emanating from the activated container to determine the vapor's ignition potential. A description of each test performed with the individual MRE is shown in table 1.

TABLE 1. CONDITIONS FOR THE INDIVIDUAL MRE TESTS

Test	Condition
1	MRE heated according to provided directions. Internal temperature of MRE container monitored.
2	Nonactivated FRH placed on supplied Styrofoam and both were lit with a match.
3	FRH activated by salt water and surrounded by shredded paper.
4	FRH activated by salt water and placed on supplied Styrofoam. FRH and Styrofoam surrounded by shredded paper.
5 and 6	MRE heated according to provided directions. Ignition source held to vapors emanating from packaging.

IGNITION TESTING OF MULTIPLE MREs IN A CONFINED AREA.

In addition to the individual MRE tests, experiments were performed with multiple FRH MREs inside a small, vented tank. In each of these cases, the FRHs were activated and ignition was attempted by initiating a high-power spark within the tank.

The test article was constructed of 1/4-in. aluminum with internal dimensions of 3′ by 3′ by 1′ in height for a total internal volume of 9 ft^3. A 10″ by 10″ opening in the test article's roof was fitted with a foil diaphragm pressure relief mechanism, which for the purposes of these tests was not fully sealed. Three K-type thermocouples monitored air temperatures within the tank throughout testing.

A spark/arc gap was located in the front left corner of the tank. This gap consisted of two 1/16-in.-diameter tungsten electrodes that used a micrometer for gap width control and adjustment springs for electrode alignment. The gap width was set at approximately 7 mm throughout testing. Power was supplied to the spark gap via an oil burner transformer, shown in previous experiments to provide a spark energy of approximately 0.5-0.8 Joules/second [2].

A total of four tests were conducted in this apparatus with a varying number of FRHs MREs located inside in several different configurations. More details of these tests and results are discussed in the section Results of Ignition Testing of Multiple MREs in a Contained Area.

DISCUSSION OF RESULTS

INDIVIDUAL MRE TEST RESULTS.

Test 1 consisted of the MRE being heated under normal operation according to the supplied directions. The temperature within the box was monitored and a peak reading of 150°F was observed. For test 2, a nonactivated FRH was placed on its Styrofoam tray and out in the open (not placed back in the box). A match was used to light both the Styrofoam tray and the FRH. It was observed that the Styrofoam burned significantly more than the FRH did.

Tests 3 and 4 consisted of placing an activated FRH by itself (test 3) and with the enclosed Styrofoam (test 4) in a container of shredded paper. Both tests resulted in no visible burning of the surrounding shredded paper.

In tests 5 and 6, an MRE was heated under normal conditions, as in test 1, but an ignition source in the form of a match was used to ignite the vapors emanating from the MRE box. Temperatures in excess of 215°F were recorded inside the box. When lit with the match, the vapors produced an ignition event. The side of the box was blown open, and flames emitted from the box, which can be seen in figure 3.

FIGURE 3. PHOTOGRAPH TAKEN FROM A VIDEO OF IGNITION EVENT OCCURING IN AN MRE UNDER NORMAL OPERATION

RESULTS OF IGNITION TESTING OF MULTIPLE MREs IN A CONFINED AREA.

The first of these tests was conducted with three MREs placed inside the small, vented tank as shown in figure 4. The FRH of each MRE was activated and the MRE was placed back into the box as described in the MRE directions. The top of the tank was sealed and the igniter was activated to provide a continuous high-energy arc inside the tank. The meals were allowed to cook for 15 minutes and throughout that time no reaction was observed. The monitored temperature within the tank peaked at approximately 90°F, up from an initial starting temperature of approximately 72°F. The temperature profile from this test is shown in figure 5.

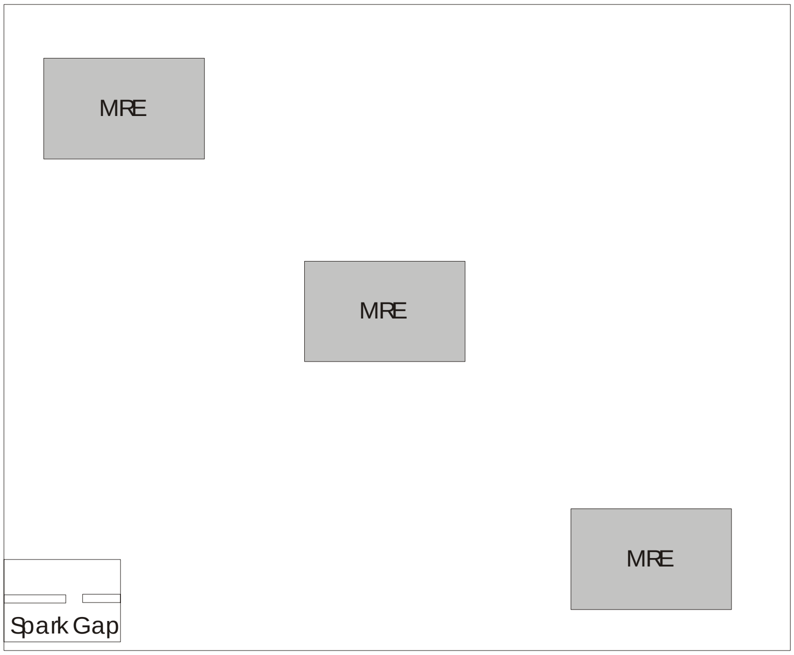

FIGURE 4. CONFIGURATION OF MREs FOR IGNITION TEST 1

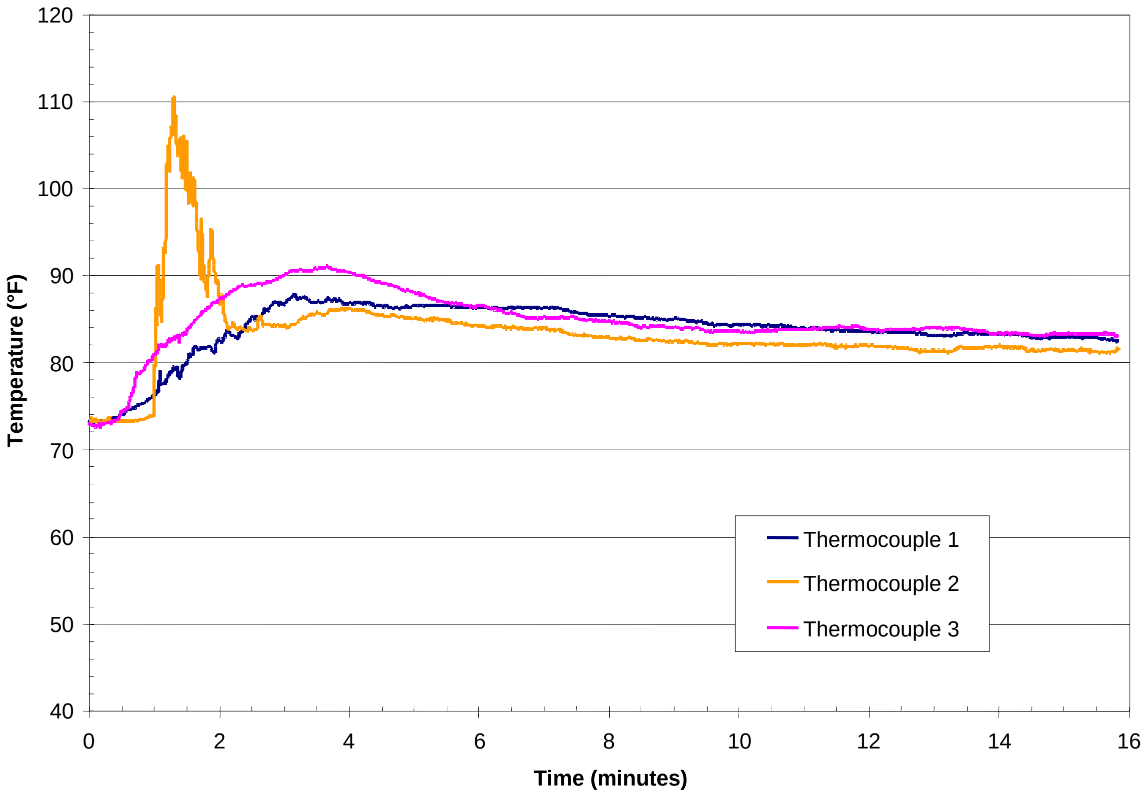

FIGURE 5. TEMPERATURE PROFILES FOR IGNITION TEST 1

The next test was conducted with six FRH packets placed on top of the Styrofoam tray without the meal or box. The trays were arranged as shown in figure 6. As in the first test, the igniter was activated to provide a continuous high-energy arc. In this instance however, a quick puff of smoke was released through the vent hole and through leaks in the tank seals. After this initial surge of smoke, a slow, continuous stream of smoke could be seen emanating from the tank's vent hole. As the igniter was intermittently initiated after this, small surges of smoke could also be seen coming from the tank's vent. Upon completion of the test, two of the six Styrofoam trays were visibly burnt from the reaction that had occurred within the tank. The temperature profile from this test can be seen in figure 7. From this plot, it is observed that the peak temperatures recorded by the three thermocouples range from approximately 140° to 160°F.

Test 3 was conducted identically to the previous test, but with four FRH trays instead of six. The trays were placed near each corner of the tank. Observances in this test were identical to test 2 but with a noticeably smaller volume of smoke. The temperature profile for this test is unavailable due to issues arising in the data acquisition system during this test; however, the observed peak temperature range was approximately 120°-125°F, with an initial tank temperature of approximately 73°F.

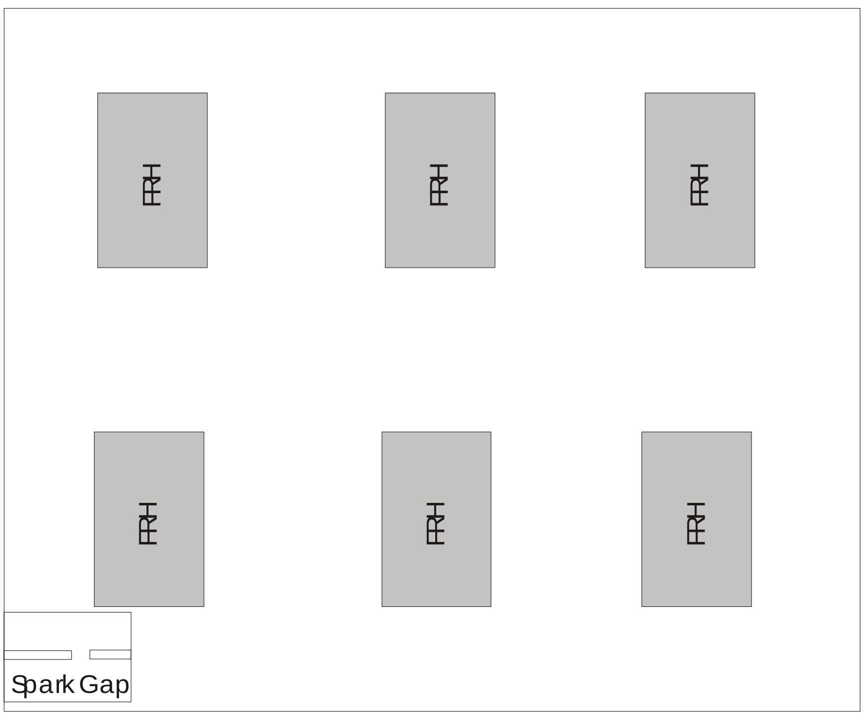

FIGURE 6. CONFIGURATION OF FRHs FOR IGNITION TEST 2

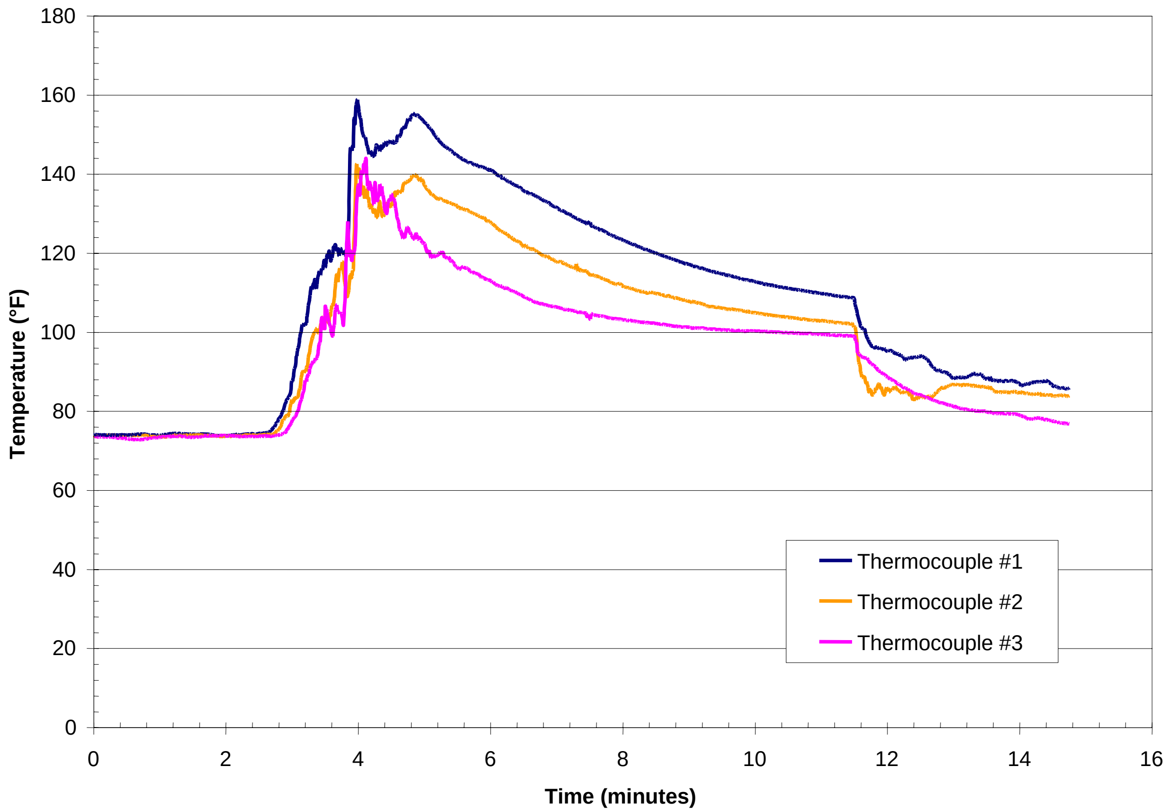

FIGURE 7. TEMPERATURE PROFILES FOR IGNITION TEST 2

The final test of this series was conducted with five FRH packets, again placed on top of the Styrofoam trays with no meal or box. The trays were arranged as shown in figure 8. However, in this test, the igniter was not initiated until approximately 3 minutes after the FRH packets were activated. This provided sufficient time for the tank to achieve its peak temperature, as well as for any flammable vapors emanating from the FRH packets to accumulate. A violent and rapid ignition was achieved in this test, rupturing the tank's pressure relief mechanism. Flames emanated from the tank. A series of still photographs taken from video of the ignition event is shown in figure 9. The temperature profiles from this test can be seen in figure 10. The ignition event can easily be seen in this plot since all three thermocouples display a rapid increase in temperature at a timestamp of approximately 4 minutes. The increase in temperature resulted in a peak tank temperature of 164°F.

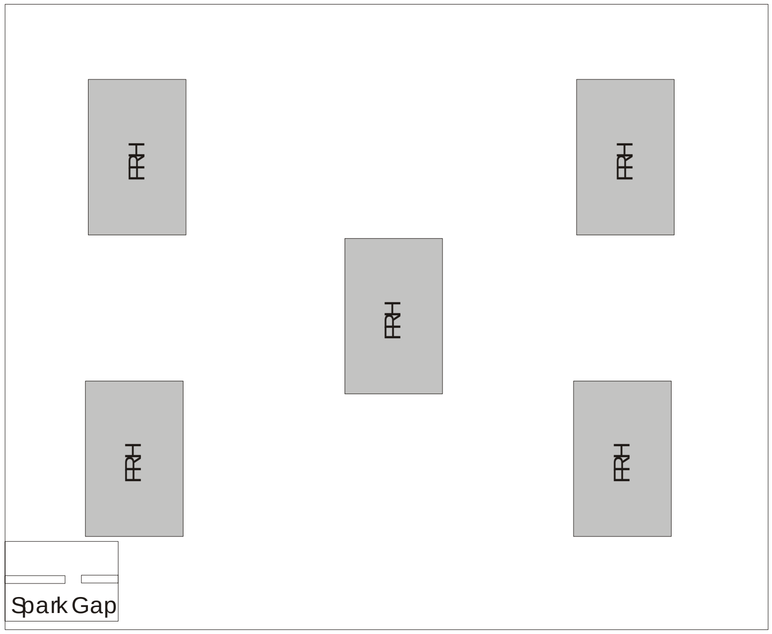

FIGURE 8. CONFIGURATION OF FRHs FOR IGNITION TEST 4

(a)

(b)

(c)

FIGURE 9. STILL PHOTOGRAPHS TAKEN FROM VIDEO OF IGNITION TEST 4 AT (a) TIME = 0.00 s, (b) TIME = 0.47 s, AND (c) TIME = 2.33 s

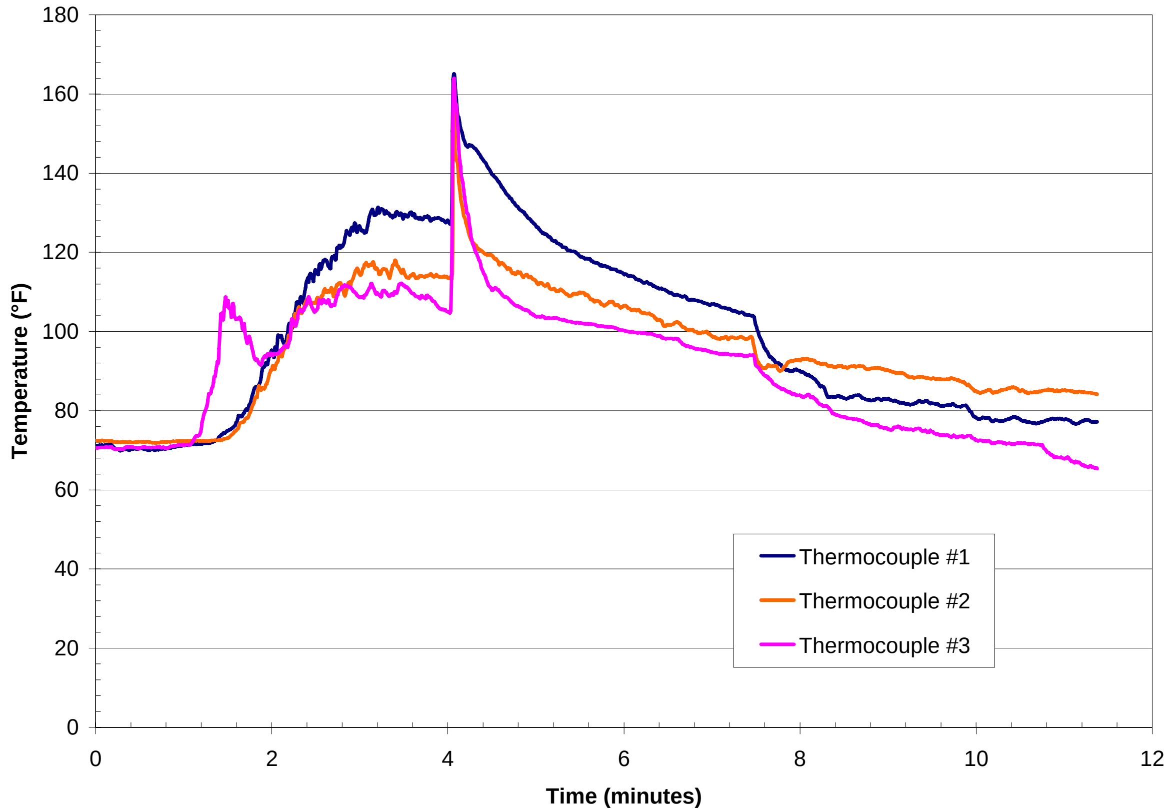

FIGURE 10. TEMPERATURE PROFILES FOR IGNITION TEST 4

SUMMARY

Tests were performed with individual MREs in an open environment and multiple MREs in a confined space to examine the potential hazard associated with their use in an aircraft cabin. The tests also examined accidental activation of FRHs in a confined area aboard the aircraft, such as in overhead storage bins or a cargo compartment. Temperatures in excess of 215°F and violent ignition events were observed. It is evident from the tests that the release of hydrogen gas from these MREs is of a sufficient quantity to pose a potential hazard onboard a passenger aircraft.

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