



U. S. Department of Justice

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Laboratory Report

ANAB ISO/IEC 17025:2017
Accredited Forensic Testing Laboratory

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Date of Report: April 18, 2024
Lab Number: [REDACTED]
Reference: [REDACTED]
Title of Investigation: Fire - Spirit of Boston
Type of Exam: Engineering – Analysis

EXAMINATION REQUEST

The ATF Fire Research Laboratory (FRL) received a memorandum requesting technical assistance from Special Agent/ Certified Fire Investigator (SA/CFI) M [REDACTED] H [REDACTED] dated September 25, 2023 [1]. It was requested that the FRL conduct testing to evaluate ignition scenarios for a Sterno[®] Stem Wick chafing fuel can and a plastic dolly glass rack. It was also requested that the FRL characterize the burning behavior of plastic glass racks in a compartment to evaluate fire timeline.

BACKGROUND

On March 24, 2023, a fire occurred aboard the Spirit of Boston dinner cruise ship. The fire scene examination determined that the fire originated in the port side aft wait station (Figure 1). The wait station contained plastic service items and was used as a staging area for food service [1]. Figure 2 shows a Sterno can resting on its side embedded at the bottom of resolidified plastic recovered from the room of origin. Figure 3 shows undamaged Sterno cans recovered from the Spirit of Boston.

In a phone conversation on October 17, 2023, SA/CFI H [REDACTED] stated that smoke was observed by witnesses and on video camera being pushed out of the room of fire origin and over the pony wall shown in Figure 4 [2].

APPROACH

Testing and analysis were conducted in three phases. For a detailed description of all materials and methods used in testing consult the ATF FRL Project Records for this case [3] [4] [5]. Note, Sterno[®] Stem Wick chafing fuel cans will be referred to as Sterno cans from this point forward in the report. Figure 5 shows a Sterno can which was typical of those used in all testing and is consistent with the burned and undamaged cans recovered from the scene.

Phase 1: Sterno can characterization tests

A total of 12 experiments were conducted to document the burning characteristics of Sterno

cans. Table 1 is a test matrix for all Phase 1 testing. For detailed information regarding this testing see the ATF FRL Project Record [3].

Experiments 1 through 5 were conducted to document the heat flux above the flame from a burning Sterno can at three different distances: 12 cm (4 7/8 in.), 17 cm (6 5/8 in.), and 19 cm (7 1/2 in.). The distances pertain to locations measured from the ground to three different points on the bottom of Edward Don brand plastic dolly carts. Figure 6 and Figure 7 show the top and bottom of a tested dolly cart, respectively. Figure 8 shows the location of the three different measurement points annotated with red circles. The measurement points correspond to three different elevations above the ground. The Sterno can was placed both upright (Figure 9) and on its side (Figure 10) during testing. Experiments 2 through 5 were conducted in an enclosure to produce a quiescent environment that reduced flame movement.

Experiment 6 was conducted to evaluate the ignitability of spilled Sterno chafing fuel using a stick lighter (Figure 11). Experiment 7 was conducted to document the burning time of a Sterno can after all liquid fuel was poured out of the can. Experiments 8 through 12 were conducted to document the propensity of lit Sterno cans dropped to the ground to remain lit. Figure 12 is representative of the test set-up for Experiments 8 through 12. The tests conducted in Phase 1 are summarized in Table 1.

Table 1. Phase 1 Test Matrix

Exp. No	Test Description	Scenario Description
1	Heat Flux Characterization of Sterno Can	Sterno can positioned on its base. Measurement located 12 cm (4 7/8 in) from floor.
2	Heat Flux Characterization of Sterno Can	Sterno can positioned on its base. Measurement located 12 cm (4 7/8 in) from floor.
3	Heat Flux Characterization of Sterno Can	Sterno can positioned on its side. Measurement located 12 cm (4 7/8 in) from floor.
4	Heat Flux Characterization of Sterno Can	Sterno can positioned on its base and then side. Measurement height 17 cm (6 5/8 in).
5	Heat Flux Characterization of Sterno Can	Sterno can positioned on its base and then side. Measurement height 19 cm (7 1/2 in).
6	Ignition of Sterno Can Fuel Spill with Lighter	Sterno can positioned on its side. Attempted ignition of pooling fuel.
7	Burning Duration	Fuel poured out. Only remaining fuel in wick.
8	Drop Tests	5 full Sterno cans lit and dropped from height of approximately 40 inches on to gypsum wallboard.
9	Drop Tests	10 full Sterno cans lit and dropped from height of approximately 40 inches on to gypsum wallboard.
10	Drop Tests	10 full Sterno cans lit and dropped from height of approximately 40 inches on to gypsum wallboard.
11	Drop Tests	10 full Sterno cans lit and dropped from height of approximately 40.5 inches on to concrete.



Exp. No	Test Description	Scenario Description
12	Drop Tests	10 full Sterno cans lit and dropped from height of approximately 40.5 inches on to concrete.

Phase 2: Plastic dolly glass rack and plastic trash can ignition and burning behavior tests

A total of four experiments were conducted to document the burning characteristics of Edward Don brand plastic dolly carts and Rubbermaid brand Slim Jim plastic trashcans with a plastic liner and small quantity of trash. Fuels were ignited using Sterno cans. For detailed information regarding this testing see the ATF FRL Project Record [4].

Table 2 provides experimental details for the four experiments conducted in this phase. Experiments 1 and 2 were conducted by placing a Sterno can beneath a dolly. Figure 13 shows where the Sterno cans were placed for Experiments 1 and 2.

Experiments 3 and 4 were conducted by placing a lit Sterno can into the contents of a Rubbermaid brand Slim Jim 23 gallon trash can (Figure 14). Each trash can was black in color and was lined on the inside with a trash bag. Figure 15 shows the general test set-up for Experiments 3 and 4. Four trashcans were tested during each experiment. Each trash can was filled, in general, with the same fuels. Figure 16 shows the trash contents placed into each can.

Table 2. Phase 2 Test Matrix

Exp. No	Test Description	Scenario Description
1	Ignition of Edward Don Dolly Cart	Ignition using Sterno Can positioned under edge of cart
2	Ignition of Edward Don Dolly Cart	Ignition using Sterno Can positioned under center of cart
3	Ignition of Trash Can Contents	Sterno can placed in 4 Slim Jim Trash Cans with Bags, and Trash Can Fuel Package
4	Ignition of Trash Can Contents	Sterno can placed in 4 Slim Jim Trash Cans with Bags, and Trash Can Fuel Package

Phase 3: Compartment fire testing

A total of seven experiments were conducted to evaluate fire growth and spread of plastic combustibles within a simulated full-scale boat wait station. During each experiment, a Sterno can, placed on its side, was used as the ignition source. For detailed information regarding this testing see the ATF FRL Project Record [5].

Each experiment was performed in a structure that was sheathed in gypsum wallboard. The structure was the same size as the wait station and surrounding areas of the Spirit of Boston, the dimensions of which are shown in Figure 17. The walls highlighted in red and green represent two pony walls, with their heights provided in a legend on the right side of Figure 17. The vertical distances between the pony walls and test structure ceiling were the same distances as

those measured between the pony walls and drop ceiling on the Spirit of Boston. Figure 18 through Figure 20 show the test structure prior to the first experiment.

Multiple plastic items were placed into the wait station prior to the start of each test and provided fuel for test fires. Plastic items included two different types of glass racks and a flatware basket, a utility cart, and the aforementioned plastic dolly and trashcan. As shown in Figure 21, the blue and grey glass rack affixed on the dolly cart was a Cambro 25 CUP Glass Rack Navy with Grey. The glass racks were composed of polypropylene and measured 50 cm square × 27 cm high (19.75 in. square × 10.5 in. high). The beige glass rack shown in Figure 21 was the Vollrath CR6 Traex Glass Rack with 25 Compartments. This glass rack was composed of a copolymer plastic and measured 50 cm square × 10 cm high (19.75 in. square × 4 in. high). Figure 21 also shows the Vollrath 1371 Utensil Basket in beige. The utensil basket measured 43 cm × 22 cm × 15 cm (16.9 in. × 8.5 in. × 5.9 in.).

The utility cart was composed of black polyethylene and measured 91 cm × 61 cm × 79 cm (36 in. long × 24 in. wide × 31.25 in. high) (Figure 22). Four 13 cm (5 in.) casters were affixed to the bottom four corners of the lower shelf.

The aforementioned plastic dolly was also used during this test series. See Figure 6 and Figure 7.

The 23 gallon Rubbermaid Slim Jim trash can was also used during this test series (Figure 14). Each trash can was lined on the inside with a trash bag. Each trash can was filled, in general, with the same fuels. As shown in Figure 24, fuels included a plastic cup, paper coffee filter, plastic stirring straw, paper sweetener packet and a paper towel.

Five different fuel configurations were used during this testing and are summarized in Table 3. Schematics showing each fuel configuration are presented in Figure 25. At the start of each experiment, other than Experiment 5, the Sterno can was lit and placed on its side in a position with the wick facing away from the wait station doorway. Each experiment began when the dolly cart was set in position over top of the lit Sterno can.

Prior to the start of Experiment 5 the Sterno can was lit. The experiment was started when the lit Sterno can was placed on its side into the trash can

Table 3: Phase 3 Test Matrix

Exp. No	Scenario Description
1	Fuel Configuration 1
2	Fuel Configuration 1. Dolly cart conditioned for 24 hours
3	Fuel Configuration 1. Dolly cart conditioned for 24 hours
4	Fuel Configuration 2. Dolly cart conditioned for 24 hours
5	Fuel Configuration 3

Exp. No	Scenario Description
6	Fuel Configuration 4. Dolly cart conditioned for 24 hours
7	Fuel Configuration 5. Dolly cart conditioned for 24 hours

EXAMINATION/ANALYSIS AND INTERPRETATION OF RESULTS

RESULTS

Phase 1:

Table 4 provides a summary of the heat flux results. The maximum heat flux recorded during the test is provided in the “Maximum” column. The “Maximum Average” columns are calculated over pre-determined time spans. For Experiments 2 to 5, an attempt was made to center the flame and convective plume directly beneath the heat flux transducer. The flames were laminar but exhibited a high degree of pulsation and movement due to local air movement around the Sterno can wick.

Experiments 2 through 5 incorporated a box enclosure around the Sterno can in an attempt to limit air movement. Figure 26 shows a screen capture of video from Experiment 4 with the enclosure in place and Figure 27 shows the experiment without the enclosure. The enclosure had a dramatic effect on flame height and position as well as measured heat fluxes, which were much higher with the enclosure in place. Figure 28 is a chart of heat flux versus time for Test 4 and shows the difference in fluxes for the can in an upright position versus laying on its side. Table 4 and Figure 28 show that for the same measurement height, heat fluxes were much higher when the can was in an upright position than resting on its base. Table 4 also shows that heat fluxes decrease in magnitude with increasing distance between the flame and heat flux transducer. This trend is consistent with the heat flux measurements made above a paraffin wax candle [6].

Table 4: Measured heat fluxes (kW/m²)

Exp. No	Sterno Can Position	Transducer Height (cm/ in)	Maximum	10 Second Maximum Average	30 Second Maximum Average	1 Minute Maximum Average	5 Minute Maximum Average
1*	Base	12.4/ 4 7/8					
2	Base	12.4/ 4 7/8	66.5	59.3	56.5	55.8	52.4
3	Side	12.4/ 4 7/8	50.5	44.4	34.3	31.6	24.8
4	Base then side	16.8 / 6 5/8	49.1	31.9	30.9	28.5	23.0
5	Base then side	19/ 7 1/2	51.1	19.9	16.0	14.6	13.0

* No enclosure, results not reported due to limited test time

Experiment 6 was conducted to evaluate the ignitability of spilled Sterno chafing fuel using a stick lighter. Multiple attempts at ignition were made by holding the flame in contact with the surface of the spill. No ignition occurred during this experiment.

Experiment 7 was conducted to document the burning time of a Sterno can after all liquid fuel

was removed. A review of test video shows that the flame burned at or above the height of the wick for 10:08 (mm:ss). Shortly after this time the flame completely extinguished.

Experiments 8 through 12 were conducted to document the propensity of lit Sterno cans dropped to the ground to remain lit. Each can was pushed off a table and dropped from a height of 102 cm (40 in.). Table 5 shows if the can remained lit after falling to the floor. The last row shows the percentage of trials that the can remained lit for each experiment. A total of 45 tests were conducted. The Sterno can remained lit in 71 percent of the trials conducted after falling onto the floor.

Table 5: Results for drop tests

Sterno Can No.	Experiment No.				
	8	9	10	11	12
1	Yes	Yes	Yes	No	No
2	No	No	Yes	Yes	Yes
3	No	Yes	Yes	Yes	Yes
4	Yes	Yes	Yes	Yes	Yes
5	Yes	Yes	No	Yes	Yes
6		Yes	No	No	Yes
7		Yes	No	Yes	Yes
8		No	No	Yes	Yes
9		No	Yes	No	Yes
10		Yes	Yes	Yes	Yes
Percent Lit (%)	60	70	60	70	80

Phase 2:

Experiments 1 and 2 were conducted by placing a lit Sterno can on its base beneath a dolly. The location of plastic fuel in both of these areas was about 12.4 cm (4 7/8 in.) above the floor. The times reported for Experiments 1 and 2 are based on review of test video. Figure 29 shows ignition of the plastic dolly 54 seconds after it was exposed to flame in Experiment 1. (Note, the flame from a stick lighter was held to the Sterno can's wick for 27 seconds into the test.) Figure 30 shows when the first drip occurred at 1:14 (m:ss). Figure 31 shows the dolly burning at peak fire size at 11:44 (mm:ss). The peak fire size time was based on visual observation. Peak heat release rate (HRR) was 742 kW and occurred at 11:53 (mm:ss) based on analysis of data.

Figure 32 shows ignition of the plastic dolly 30 seconds after it was exposed to flame in Experiment 2. (Note, the flame from a stick lighter was held to the Sterno can's wick for 13 seconds into the test.) The first part of the dolly to ignite appeared to be the rubber plug under which the Sterno can was placed. Figure 33 shows when the first drip occurred at 1:14 (m:ss). Dripping did not occur until flame spread from the rubber plug to the plastic part of the dolly. Figure 34 shows the dolly burning at peak fire size at 11:20 (mm:ss). The peak fire size time was based on visual observation. Peak HRR was 853 kW and occurred at 11:40 (mm:ss) based on analysis of data. Based on the test results from Phase 1 for measured heat flux, had the Sterno

can be placed on its side or in an area of the dolly where plastic was further away from the flame, the times for dolly ignition, first drips and peak HRR would most likely have been longer.

Experiments 3 and 4 were conducted by placing a lit Sterno can into the contents of a Rubbermaid Slim Jim 23 gallon trash can. Figure 35 is a screenshot of video from Experiment 3 and shows when fire spread from the interior to the exterior of one of the four trashcans, which occurred at 6:36 (mm:ss) post ignition. At this time a portion of the chafing fuel that had spilled to the exterior of the can was burning. Figure 36 shows the trashcan burning at peak fire size 23:59 (mm:ss) after ignition.

Figure 37 is a screenshot of video from Experiment 4 and shows when fire spread from the interior to the exterior of one of the four trashcans, which occurred at 47:40 (mm:ss) post ignition. At this time a portion of the chafing fuel that had spilled to the exterior of the trash can was burning.

Phase 3:

Figure 38 through Figure 43 are photographs showing the location of the lit Sterno can beneath the plastic dolly at the start of Experiments 1 through 4 and Experiments 6 and 7. In some experiments the flame was closer to one of the protrusions at the bottom of the dolly, and in others the flame was under one of the square recesses created by protrusions.

A qualitative review of test videos, excluding Experiment 5, showed that all the fires progressed in the same manner. After the plastic dolly was placed over the lit Sterno can, the plastic began to heat until ignition occurred; following ignition, dripping plastic was observed by test witnesses. Shortly after dripping plastic was observed, sounds could be heard that were described by observers as “crackling” and “hissing”. Subsequent to crackling and hissing, the fire continued to grow in size until light smoke was observed coming out of the test structure. The quantity, opacity and smoke velocity increased as fire size increased. Tests were then suppressed. Experiment 7 was allowed to progress longer than previous experiments until the room was fully involved.

Table 6 is a summary of test times for dripping, audible crackling and hissing, and the presence of smoke. Several of the times reported in Table 6 were made from review of the test videos and are indicated as such. No times were reported for ignition of the plastic dolly as this phenomenon was not consistently observable. No times for audible events are reported in Table 3 for Test 7 as it was not recorded during testing.

Table 6: Phase 3 elapsed test result times post ignition

Exp. No	Dripping (mm:ss)	Audible crackling and hissing (mm:ss)	Smoke visible exiting structure (mm:ss)	
			Light/ visible smoke	Heavy smoke
1	18:25	20:53	22:15	23:26 [†]
2	14:54	17:32	21:31	21:38 [†]



Exp. No	Dripping (mm:ss)	Audible crackling and hissing (mm:ss)	Smoke visible exiting structure (mm:ss)	
			Light/ visible smoke	Heavy smoke
3 [‡]	4:40	6:40	7:58	9:23 [†]
4	3:05	6:07	10:21	12:58 [†]
5	n/a	n/a	n/a	n/a
6	14:24	15:05		19:17 [†]
7	2:45		9:04	10:27
MAX	18:25	20:53	22:15	23:26
MIN	2:45	6:07	7:58	9:23 [†]

† Observation made from review of test video.

‡ Sterno can repositioned at 167 seconds post ignition to ensure that flame was in contact with plastic ribbing under dolly cart.

The “Light/ Visible” smoke times observed during testing were often too faint to be observed on video. No metric was used to define “Light/ Visible” smoke and therefore there exists subjectivity between tests for reported times. (No time for this phenomenon was reported for Test 6 as it was not recorded during testing.)

“Heavy” smoke was defined as the time when smoke was consistently captured on video and could be seen from multiple perspectives. (The reader is cautioned that the times for the appearance of “Heavy” smoke on video is subjective. Additionally, the appearance of smoke aboard the Spirit of Boston with the type of cameras aboard the boat could be different than the appearance of smoke at the FRL laboratory with the cameras used during testing.)

Screenshots from a master video for Experiments 1 through 4 and Experiments 6 and 7 are presented in Figure 45 through Figure 50 and show the time at which “Heavy” smoke was visible. The master video consists of six different time synchronized test videos. Table 7 provides a location and description of the individual videos used in the master video and their perspective as it relates to the fire aboard the Spirit of Boston. The camera view in the middle of the top row in Figure 45 through Figure 50 was taken from the same perspective as the camera view in the dining area looking towards the wait station aboard the Spirit of Boston. (See Figure 4.)

Table 7: Master Video Legend

Location	Description
Top row, left	Exterior of room of origin, kitchen wall and hallway
Top row, middle	Exterior of room of origin, dining room pony wall and hallway
Top row, right	Hallway with direct line of sight to plastic fuels
Bottom row, left	Exterior window to room of origin as viewed from dock



Bottom row, middle	Doorway to room of origin
Bottom row, right	Interior of room of origin looking into the ship towards hallway

Dripping was readily observed during testing and could be seen on video. Tests conducted during Phase 2 using plastic dollies showed that in two tests dripping followed ignition in less than 30 seconds. A wide range of times for when dripping first occurred were recorded for the six tests in which dollies were ignited ranging from 2:45 (mm:ss) to 18:25 (mm:ss). (Figure 44 shows an example of plastic dripping.) This wide range of times is attributed to: (1) the distance from the wick to the plastic fuel; (2) fuel thickness and orientation where heating occurs; and (3) transitory flaming due to local air movement absent a quiescent environment.

Audible crackling and hissing could be heard by test observers approximately a couple of minutes after dripping with test times post ignition ranging from 6:07 (mm:ss) to 20:53 (mm:ss).

“Light/ Visible” smoke was reported from 7:58 (mm:ss) to 22:15 (mm:ss) post ignition. “Heavy” smoke generally followed light smoke by seconds to a couple of minutes. “Heavy” smoke was reported from 9:23 (mm:ss) to 23:26 (mm:ss) post ignition. At this time the “Heavy” smoke was a light gray color, and an orange glow produced by the fire could be seen on the surfaces of upper walls in the serving station between the vertical gap in the pony wall and the drop ceiling. Fire was confined to the dolly with plastic materials resting atop the dolly maintaining their physical shape.

Figure 51 through Figure 54 shows gas temperatures for Experiment 2 and Experiment 7, respectively. At the time “Heavy” smoke was observed on video compartment, temperatures at the ceiling measured around 100 °C to 150 °C. Approximately one minute after “Heavy” smoke was observed on video the smoke began to turn dark in color and intermittent flames could be seen between the vertical gap in the pony wall and the drop ceiling.

Table 8 shows elapsed times between sequential events including average elapsed times. The average elapsed time from placement of the Sterno can to dripping was 9:42 (mm:ss). Table 8 shows that sounds were noted by observers from less than one minute to several minutes after dripping had occurred with an average elapsed time of about two minutes. An average elapsed time of 4:17 (mm:ss) was calculated from the occurrence of audible fire cues to the appearance of heavy smoke.

Table 8: Elapsed time between events

Exp. No	Placement of Sterno can to dripping (mm:ss)	Dripping to Audible crackling and hissing (mm:ss)	Audible crackling and hissing to heavy smoke (mm:ss)
1	18:25	2:28	2:33
2	14:54	2:38	4:06
3 [‡]	4:40	2:00	2:43



Exp. No	Placement of Sterno can to dripping (mm:ss)	Dripping to Audible crackling and hissing (mm:ss)	Audible crackling and hissing to heavy smoke (mm:ss)
4	3:05	3:02	6:51
5			
6	14:24	0:41	4:12
7	2:45		
AVG	9:42	2:09	4:17

‡ Sterno can repositioned at 167 seconds post ignition to ensure that flame was in contact with plastic ribbing under dolly cart.

Figure 55 and Figure 56 show the interior of the trashcan in Experiment 5 and the exterior of the trash can following suppression, respectively. Fire failed to spread from the interior of the trashcan to the exterior.

CONCLUSION

Below is a summary of results from three phases of testing.

1. Heat flux was quantified above Sterno can flames. Testing showed that:
 - A. Sterno can flames are highly sensitive to local air movement.
 - B. One minute maximum average heat fluxes ranged from 14.6 kW/m² to 55.8 kW/m² depending upon measurement height and Sterno can orientation.
 - C. Measured heat fluxes were much higher when the can was in an upright position than resting on its side.
 - D. Heat fluxes decreased in magnitude with increasing distance between the flame and heat flux transducer.
2. Multiple attempts at ignition were made by holding the flame from a stick lighter in contact with spilled chafing fuel. No ignition of the chafing fuel occurred.
3. A Sterno can with all of its fuel poured out will burn for about 10 minutes.
4. 45 tests were conducted in which a lit Sterno can was dropped from a height of 102 cm (40 in). Sterno cans remained lit in 71% of the cases after falling onto the floor.
5. A plastic dolly was ignited by an upright Sterno can in two separate tests 30 seconds and 54 seconds after being exposed to flame. Sterno cans on their side ignited plastic approximately 2 minutes to 18 minutes after exposure. (The times for Sterno cans on their side were based on subtracting 30 seconds from the first observed dripping, per observations from Phase 2.) Ignition results are consistent with measured heat fluxes.
6. “Light/ Visible” smoke emanating from the test structure was observed from 7:58 (mm:ss) to 22:15 (mm:ss) post ignition.

- [REDACTED]
7. "Heavy" smoke was reported from 9:23 (mm:ss) to 23:26 (mm:ss) post ignition. Approximately one minute after "Heavy" smoke was observed on video the smoke began to turn dark in color and intermittent flames could be seen between the vertical gap in the pony wall and the drop ceiling.
 8. Nine individual tests were conducted, in three different experiments, by placing a lit Sterno can into the contents of a Rubbermaid Slim Jim 23 gallon trash can. Fire spread from the interior to the exterior of the trashcan in two of the tests at approximately 6:36 (mm:ss) and 47:40 (mm:ss) post ignition.

REFERENCES

1. H [REDACTED], M., Request for Technical Assistance, Fire – Spirit of Boston, ATF IN [REDACTED], September 25, 2023
2. Hartnett, M., personal communication, October 17, 2023
3. D [REDACTED], J., ATF FRL Project Record No. [REDACTED], November 2023
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6. H [REDACTED], A., B [REDACTED], M., and D [REDACTED], S. Characterization of Candle Flames. Journal of Fire Protection Engineering, 2005

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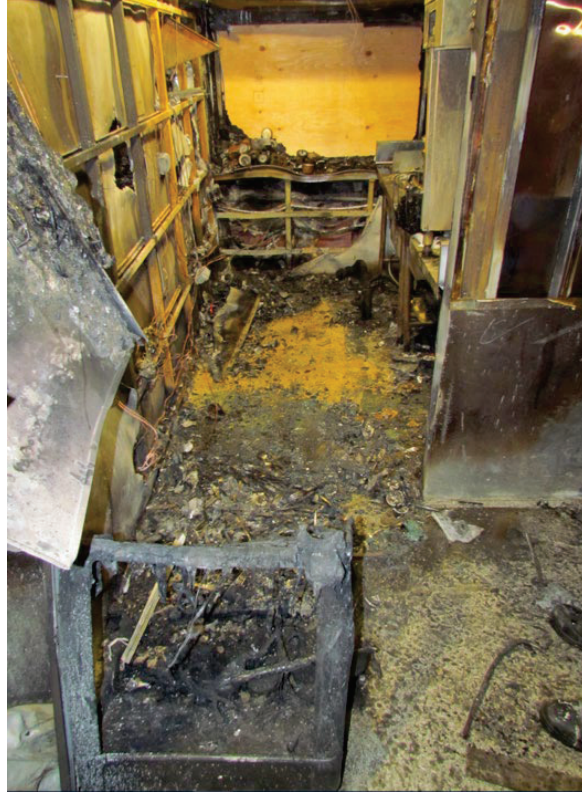


Figure 1: Room of fire origin, image rotated 90 degrees [Photo by SA/CFI H [REDACTED]] (187727_748130.JPG)



Figure 2: Bottom side of resolidified plastic recovered from room of fire origin, Sterno can resting on its side is circled in red, "Origin 3" cropped, [Photo by SA/CFI H [REDACTED]] (187727_748776.PNG)



Figure 3: Undamaged Sterno cans recovered from the Spirit of Boston [Photo by SA/CFI H [REDACTED]] (187727_748150.JPG)



Figure 4: Screenshot of video channel “CH04.h264” from camera aboard the Spirit of Boston prior to fire. Red ellipse marks the location of visible smoke on security camera.



Figure 5. Sterno Stem Wick Chafing Fuel (361069_1335966.JPG)



Figure 6: Plastic dolly cart (361138_1341098.JPG)



Figure 7: Plastic dolly cart (361138_1341099. JPG)

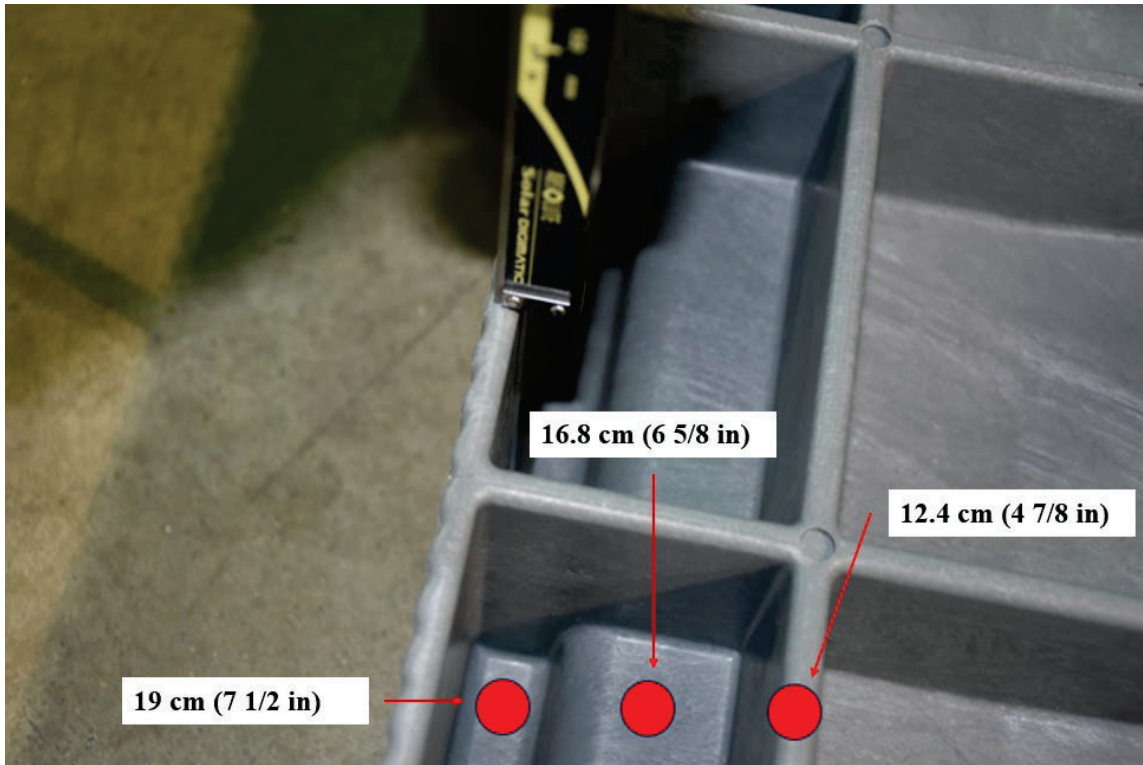


Figure 8: Close-up of bottom of plastic dolly annotated with three red dots corresponding to measurement locations (361138_1341111. JPG)



Figure 9: Phase 1, Test 4, Sterno can upright, Screen shot from video (361138_Master_1345552)

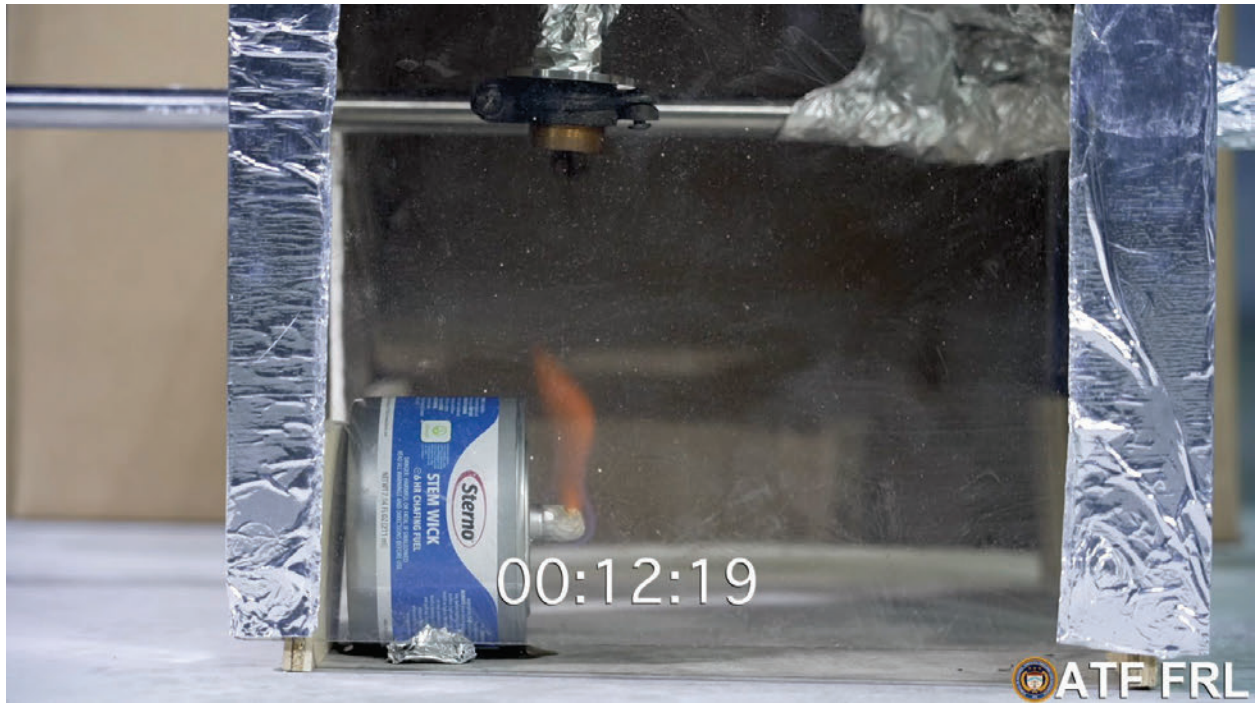


Figure 10: Phase 1, Test 4, Sterno can on side, Screen shot from video (361138_Master_1345552)



Figure 11: Phase 1, Test 6, Screen shot from video, Attempted ignition of spilled Sterno fuel when can placed on side (361154_Master_1345572)



Figure 12. Experimental Setup - Phase 1, Experiments 8 through 12 (361163_1342506.JPG)

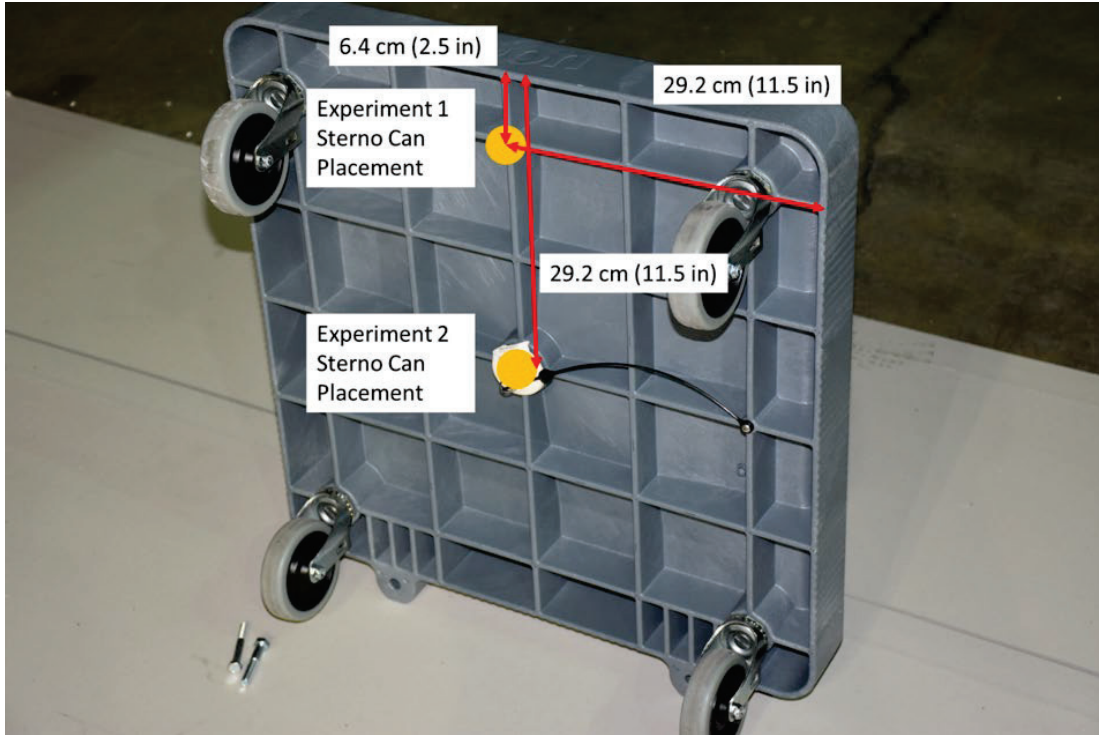


Figure 13: Sterno Can Location Phase 2, Experiments 1 and 2 (361099_1337658.JPG annotated)



Figure 14. Rubbermaid Slim Jim Trash Can (361142_1341327. JPG)



Figure 15: Phase 2, Experiment 3 and 4 Setup (361142_1341334. JPG)

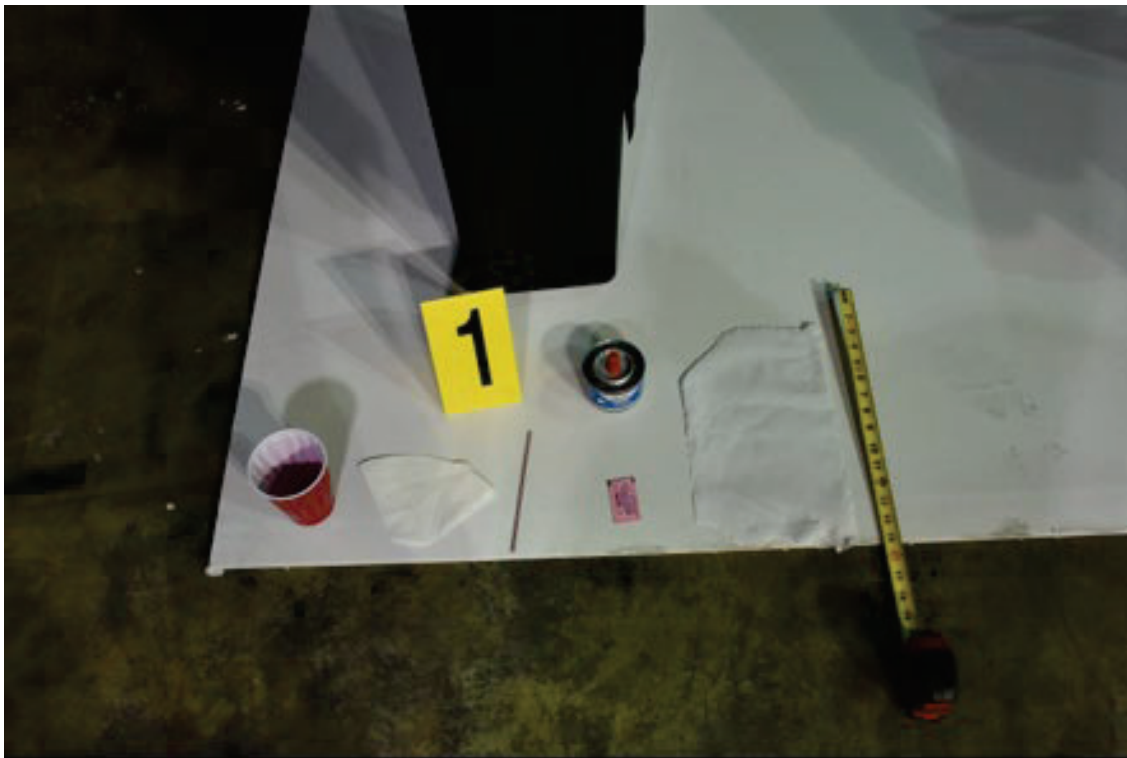


Figure 16. Phase 2, Experiment 3 and 4, Trash Can Contents (361142_1341338. JPG)

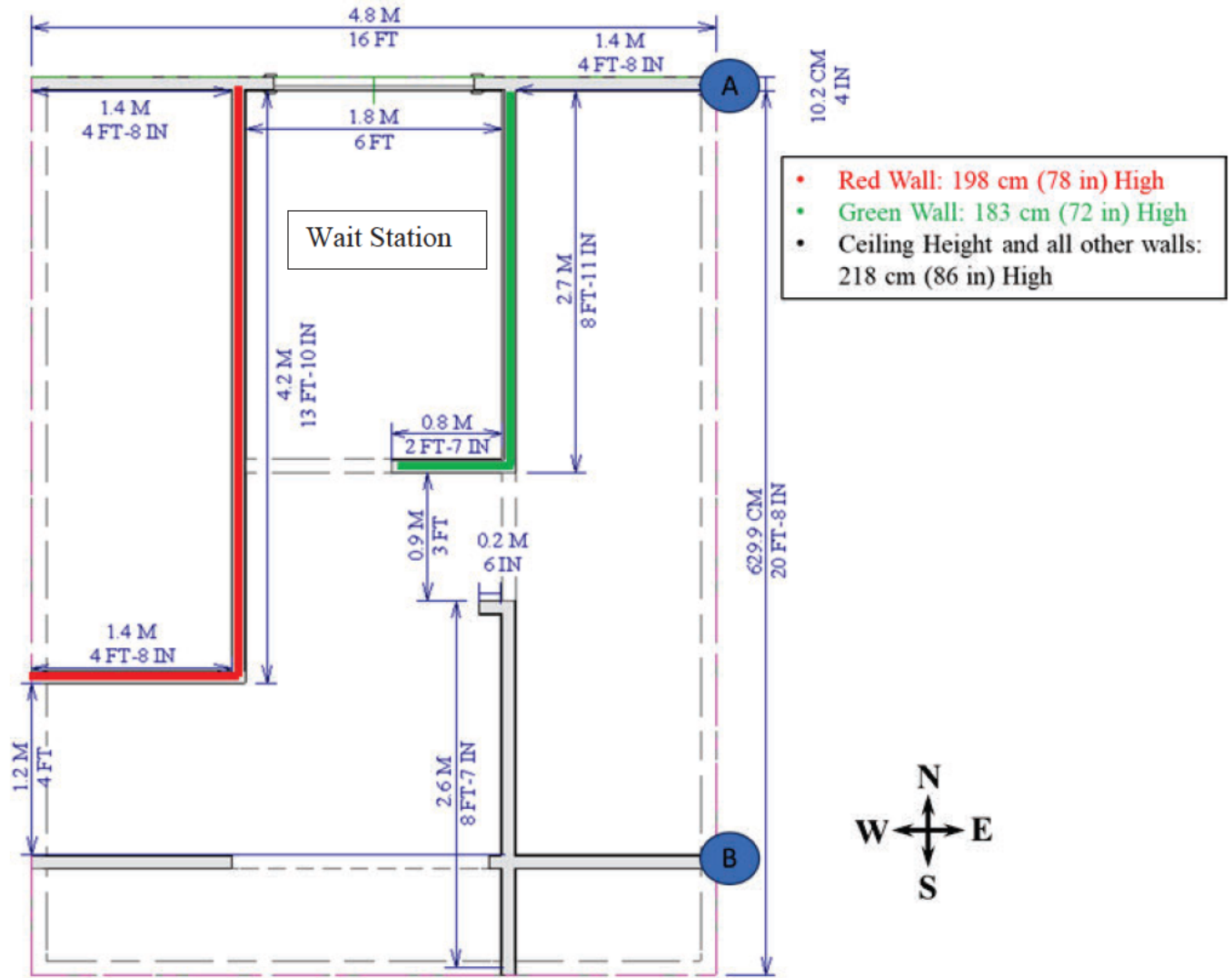


Figure 17. Test Structure (Plan View) [5]



Figure 18. Phase 3, Test structure, exterior of room of origin, kitchen wall and hallway (361029_1336737. JPG)



Figure 19: Phase 3, Test structure, hallway with direct line of sight to room of origin (361029_1336740. JPG)



Figure 20. Phase 3, Test structure, Exterior of room of origin, dining room pony wall and hallway (361029_1336734.JPG)

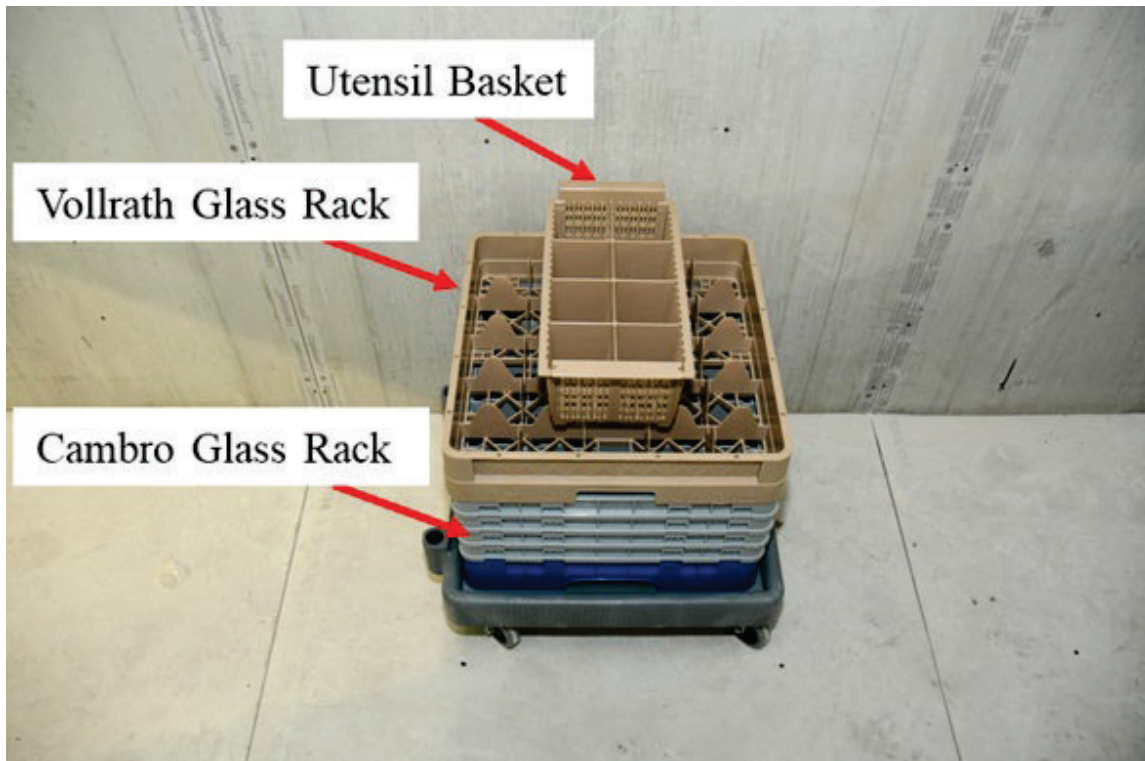


Figure 21. Glass Racks and Utensil Holder (*annotated*) (361029_1338490.JPG)



Figure 22. Utility Cart (361029_1338427.JPG)



Figure 23. Edward Don Glass Rack Dolly (361069_1335960.JPG)

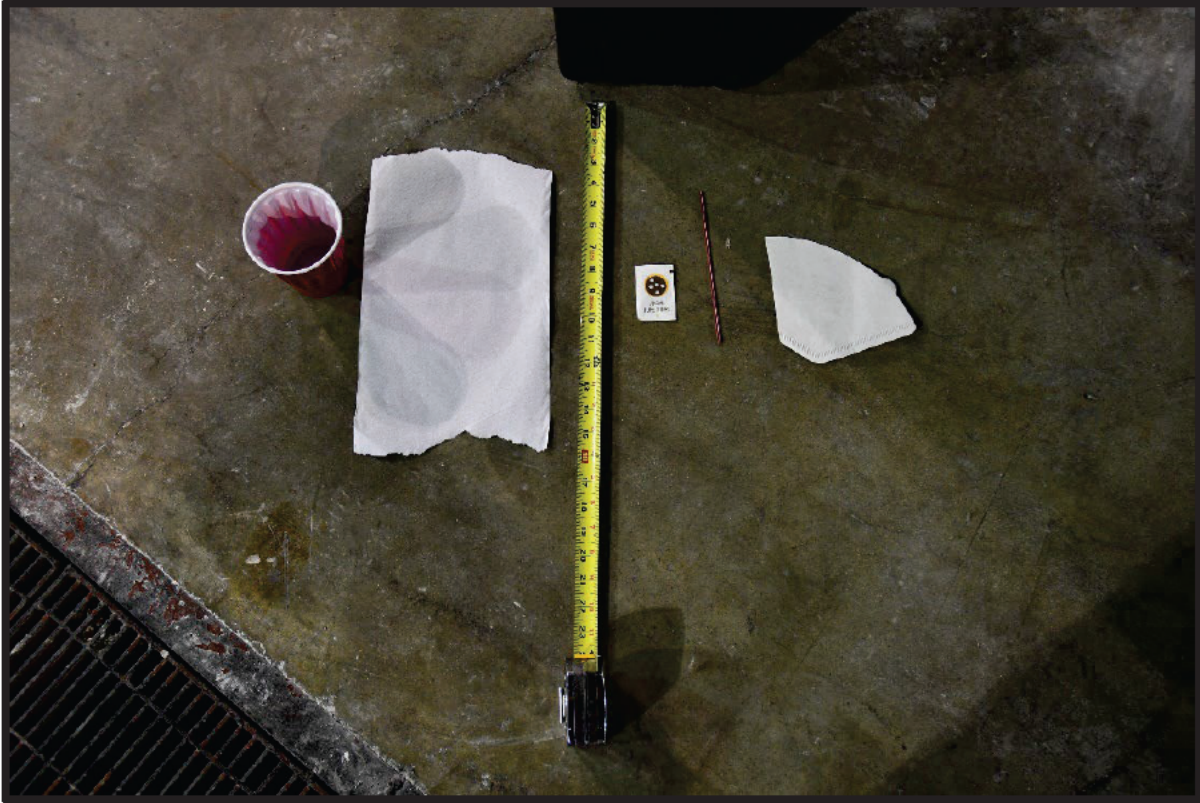


Figure 24. Trash Can Contents (361142_1341338.JPG)

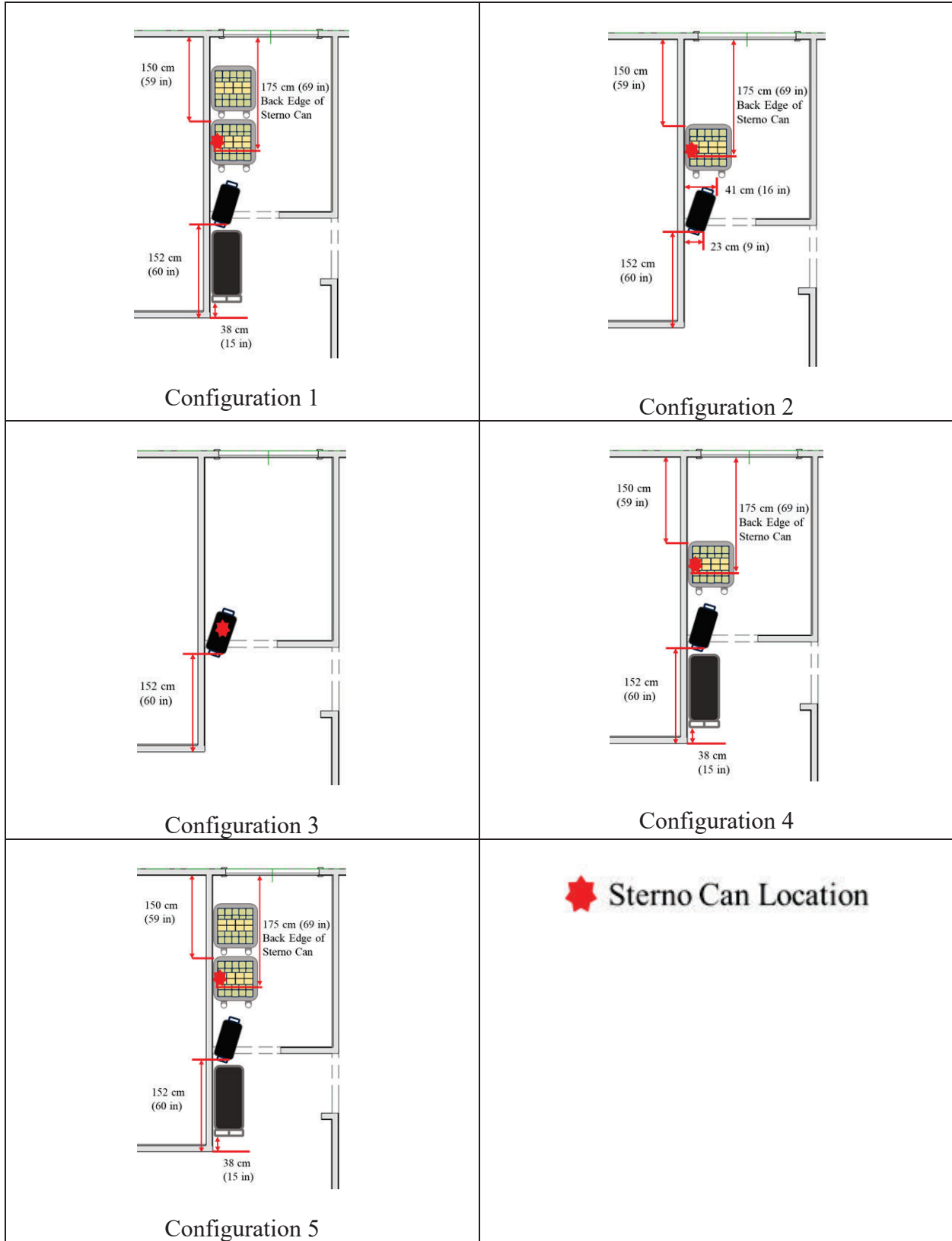


Figure 25: Fuel configuration for Phase 3 testing [5]



Figure 26: Phase 1, Test 4 (361082_Master_1345480)



Figure 27: Phase 1, Test 4 (361082_Master_1345480)

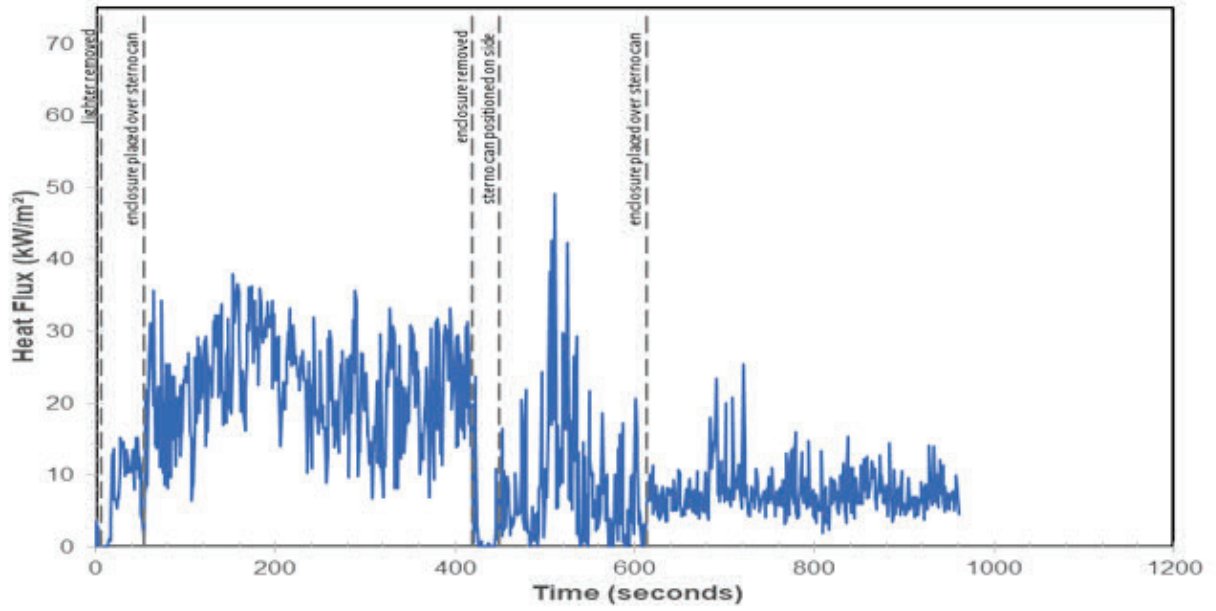


Figure 28: Phase 1, Test 4, Heat flux versus time

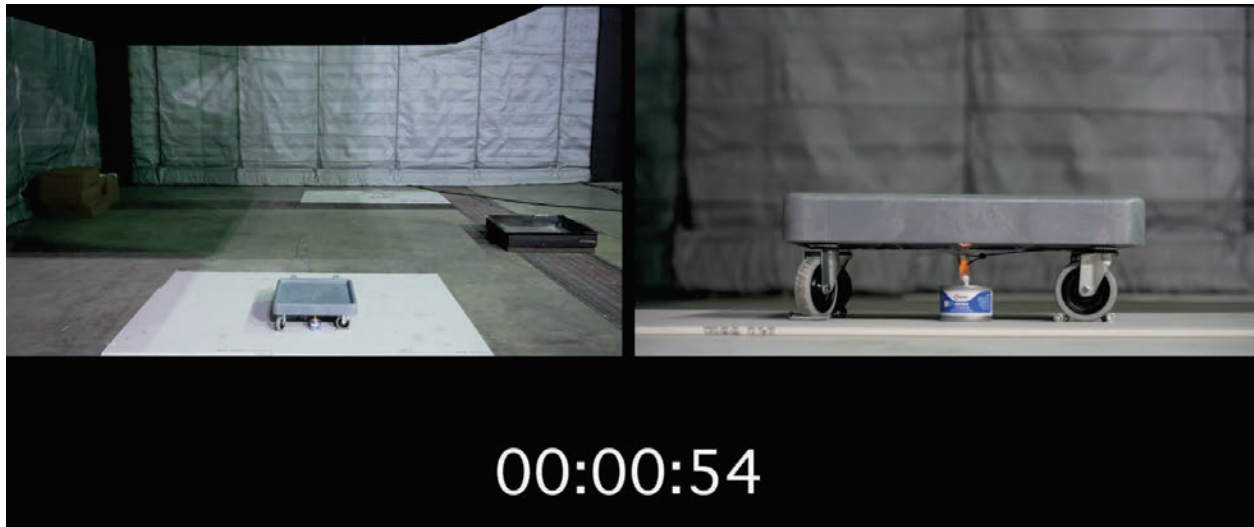


Figure 29: Phase 2, Test 1, Ignition of plastic dolly (361099_Master_1345482)

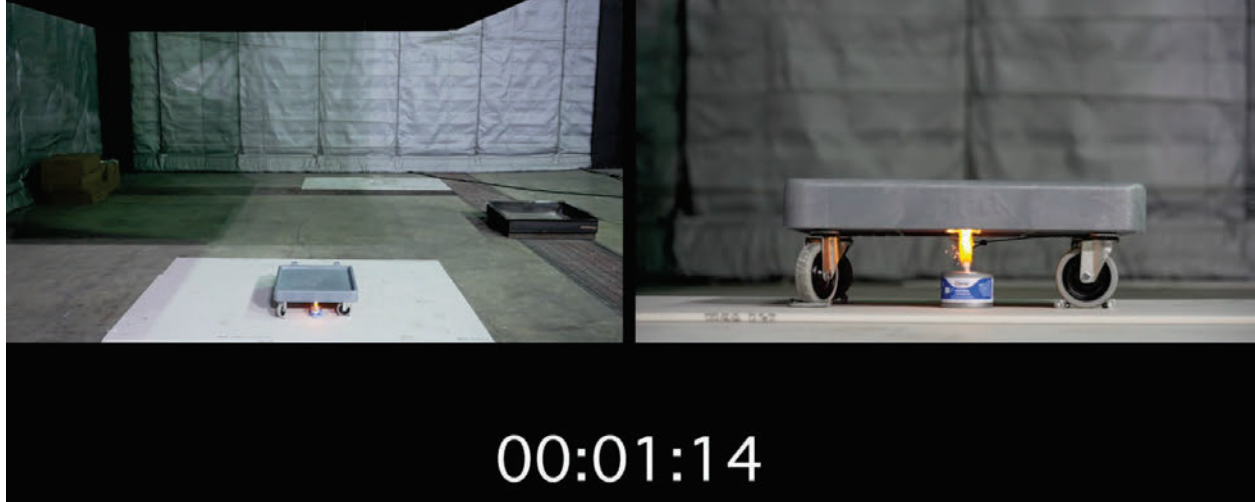


Figure 30: Phase 2, Test 1, First dripping occurs (361099_Master_1345482)

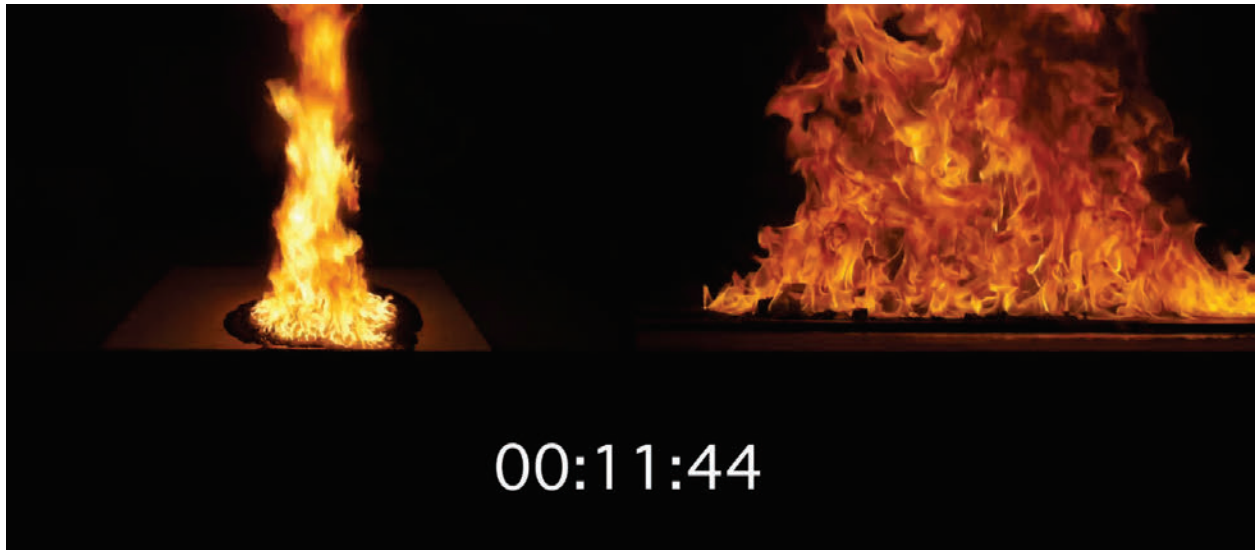


Figure 31: Phase 2, Test 1, Peak burning based on visual observation (361099_Master_1345482)

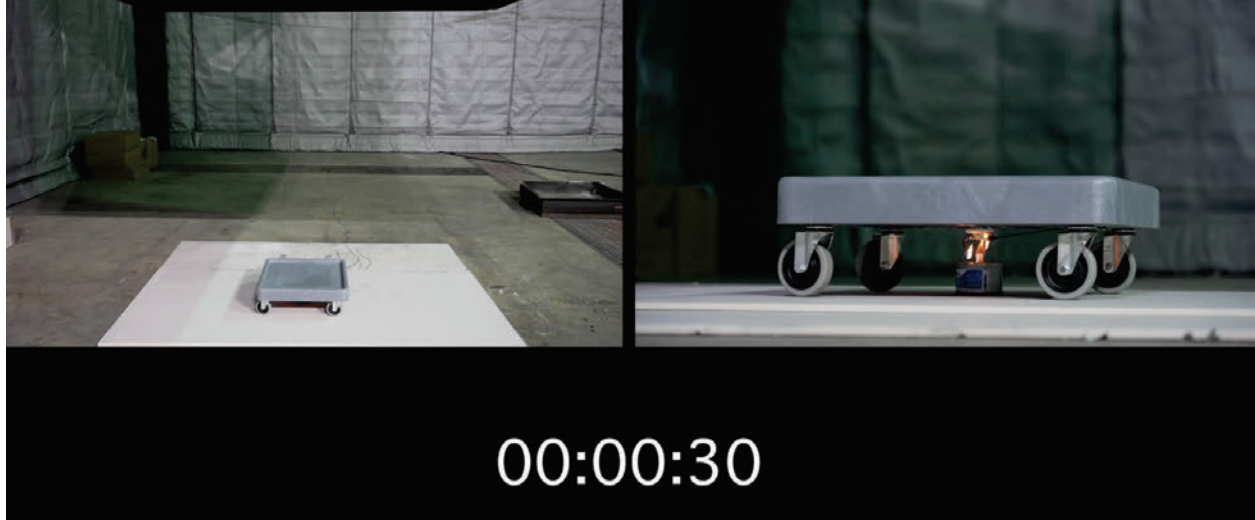


Figure 32: Phase 2, Test 2, Ignition of plastic dolly (361101_Master_1345483)

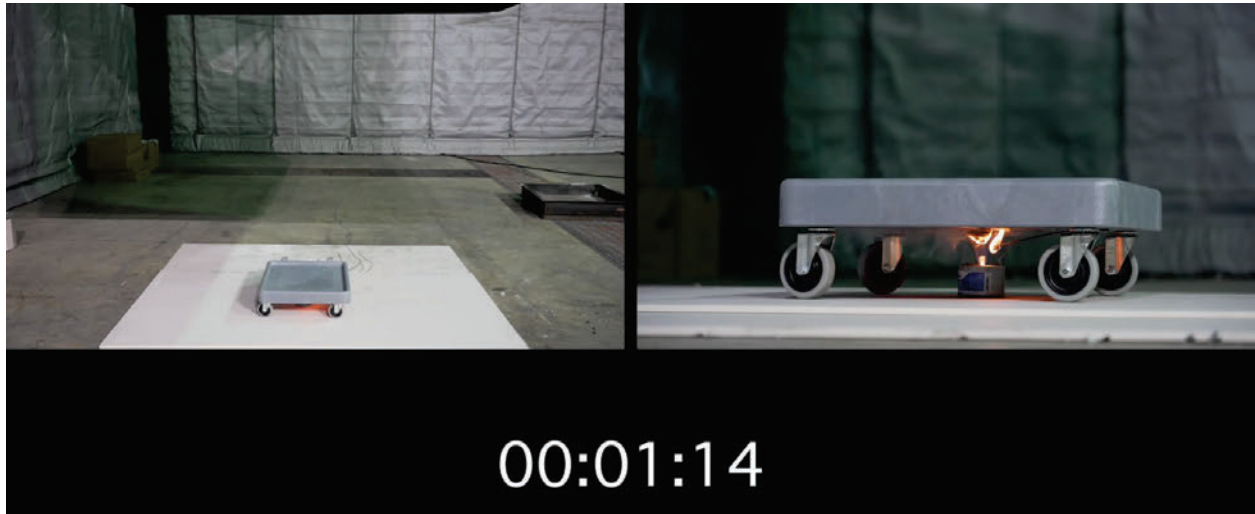


Figure 33: Phase 2, Test 2, First dripping occurs (361101_Master_1345483)



Figure 34: Phase 2, Test 2, Peak burning based on visual observation (361101_Master_1345483)



Figure 35: Phase 2, Test 3, Flame outside of trashcan 2 (361142_Master_1345553) [4]



Figure 36: Phase 2, Test 3, Peak burning based on visual observation (361142_Master_1345553) [4]



Figure 37: Phase 2, Test 4, Flame outside of trashcan 3 (361155_Master_1345575) [4]

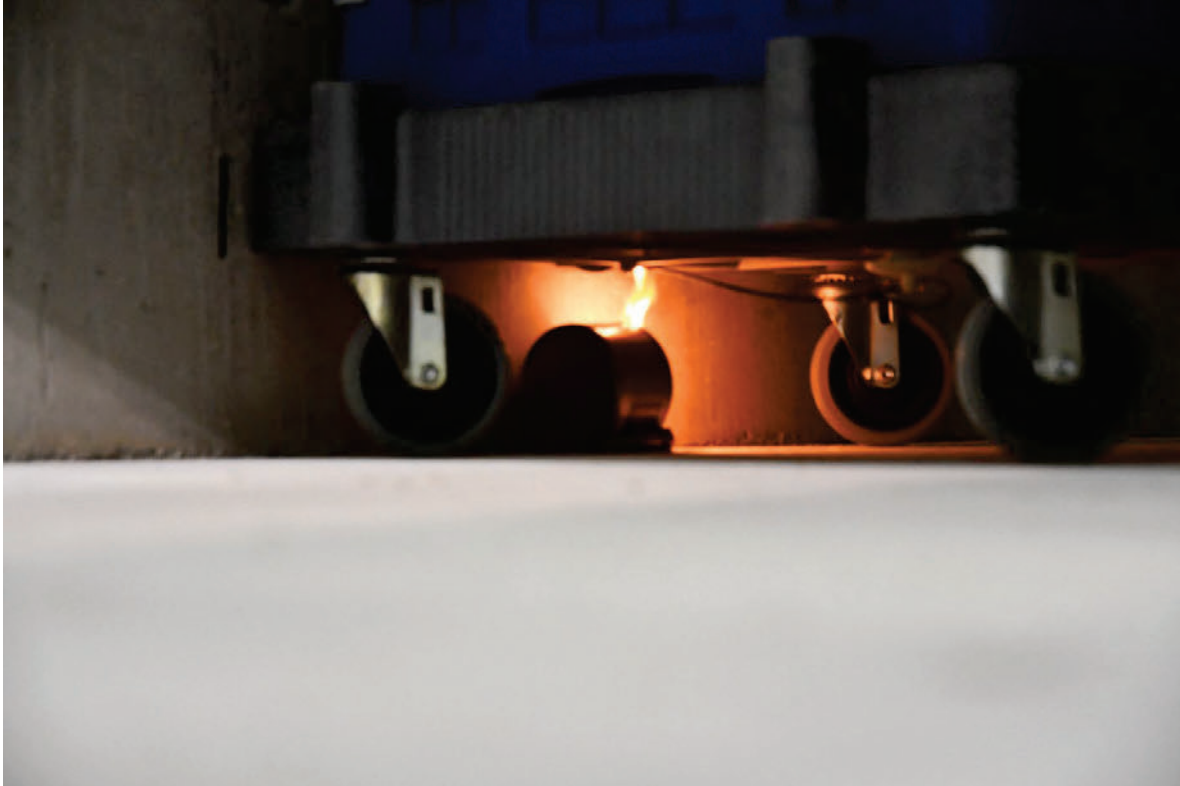


Figure 38: Phase 3, Test 1, Sterno can placement (361029_1338520.JPG)

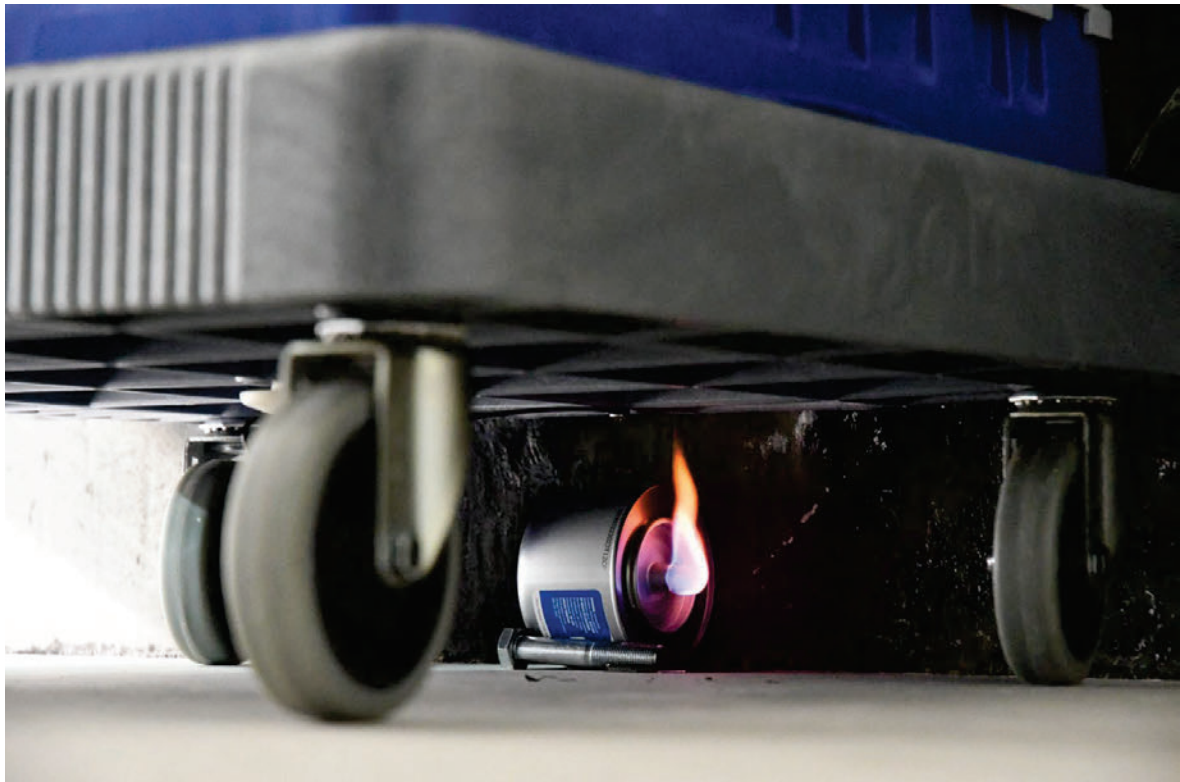


Figure 39: Phase 3, Test 2, Sterno can placement (361118_1339184.JPG)



Figure 40: Phase 3, Test 3, Sterno can placement (361119_1339535.JPG)

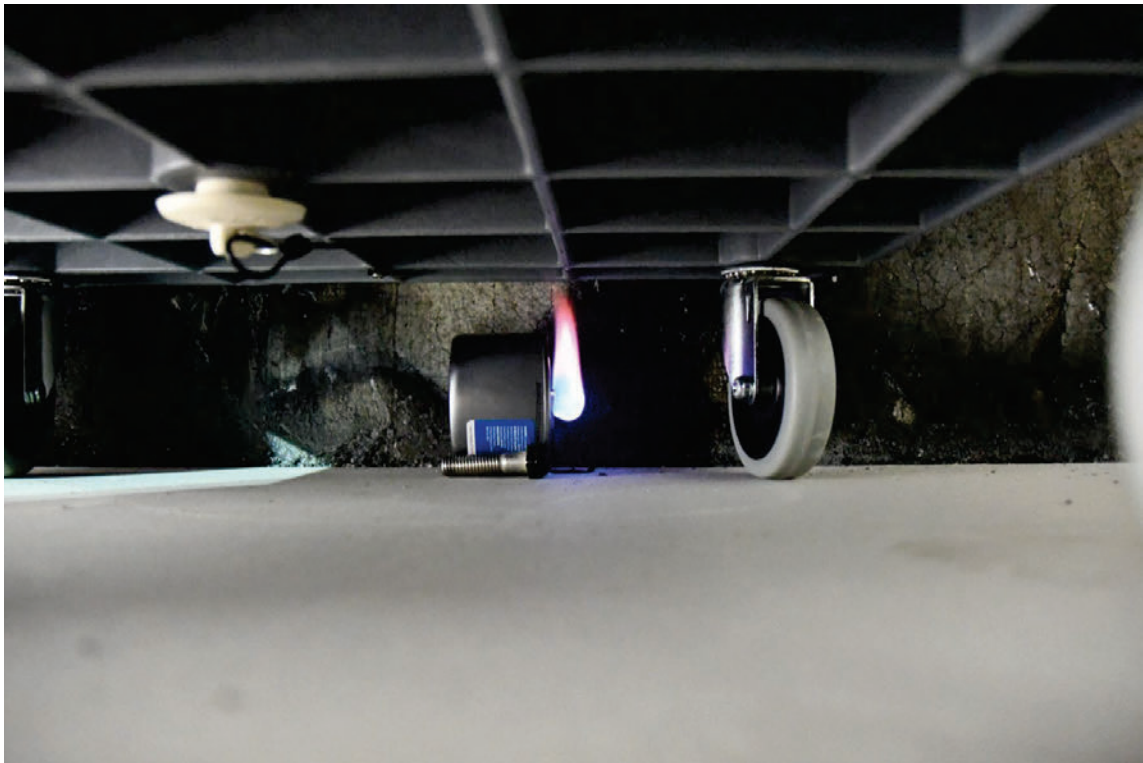


Figure 41: Phase 3, Test 4, Sterno can placement (361120_1339698.JPG)

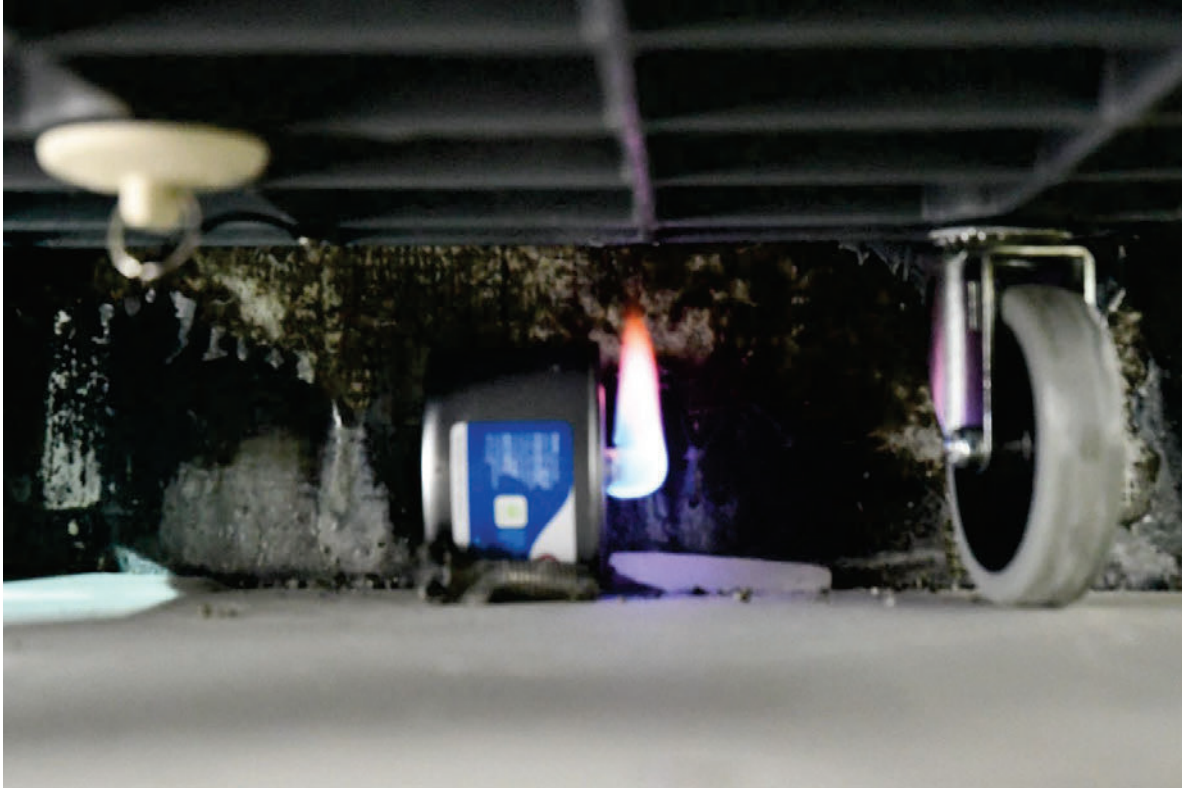


Figure 42: Phase 3, Test 6, Sterno can placement (361123_1339996. JPG)

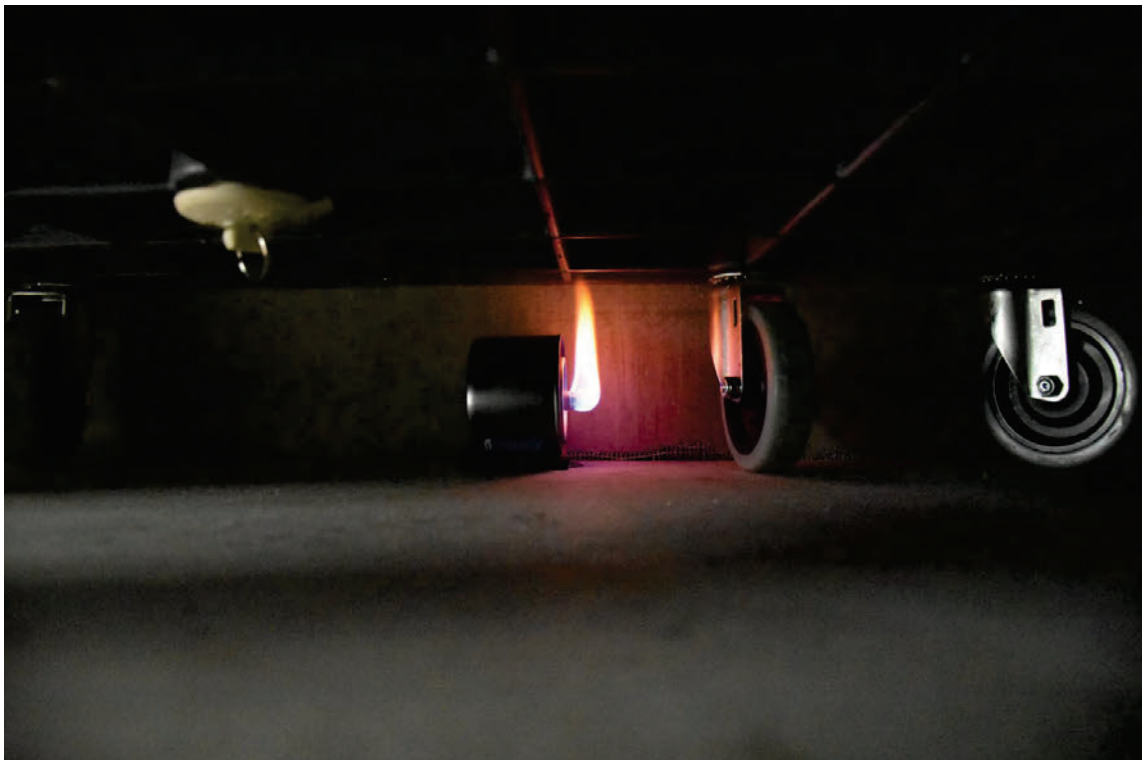


Figure 43: Phase 3, Test 7, Sterno can placement (361143_1341584. JPG)



Figure 44: Phase 3, Test 2, Dripping (361118_1339208.JPG)



Figure 45: Phase 3, Test 1 (361029_Master_1345478)



Figure 46: Phase 3, Test 2 (361118_Master_1345484)



Figure 47: Phase 3, Test 3, Sterno can repositioned at 167 seconds post ignition to ensure that the flame was in contact with plastic ribbing under dolly cart (361119_Master_1345485)



Figure 48: Phase 3, Test 4 (361120_Master_1345486)



Figure 49: Phase 3, Test 6 (361123_Master_1345488)



Figure 50: Phase 3, Test 7 (361143_Master_1345554)

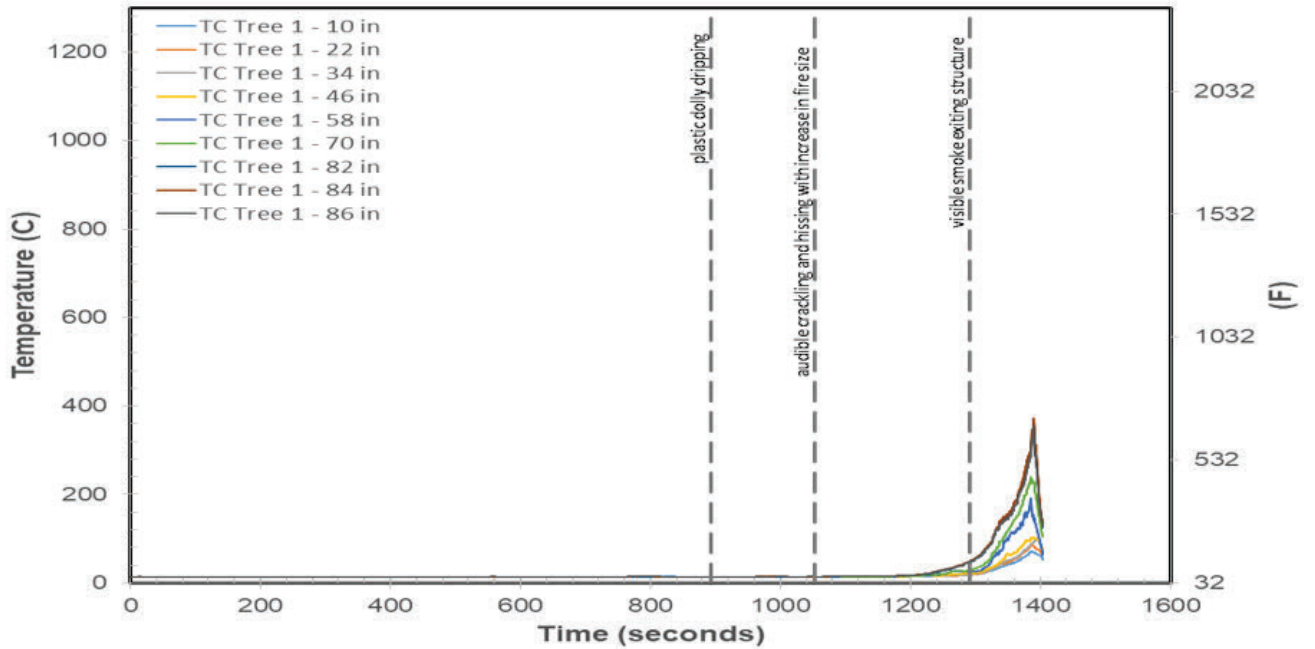


Figure 51: Phase 3, Test 2, Temperature versus time [5]

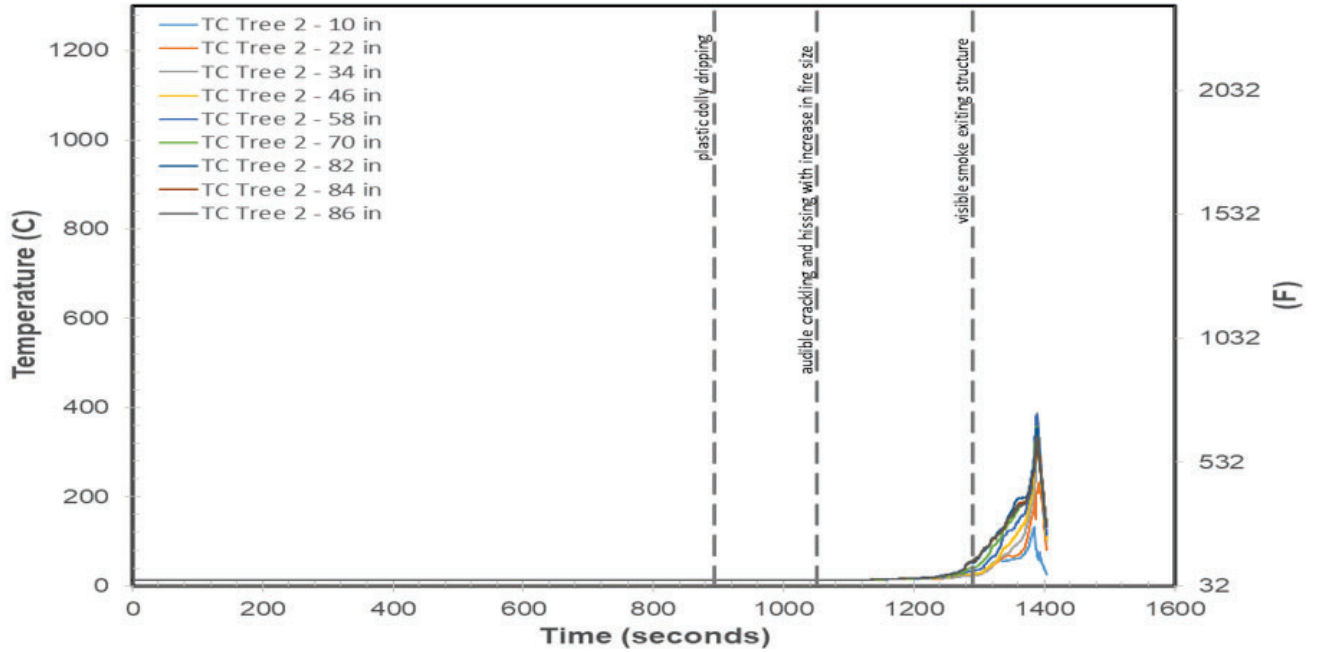


Figure 52: Phase 3, Test 2, Temperature versus time [5]

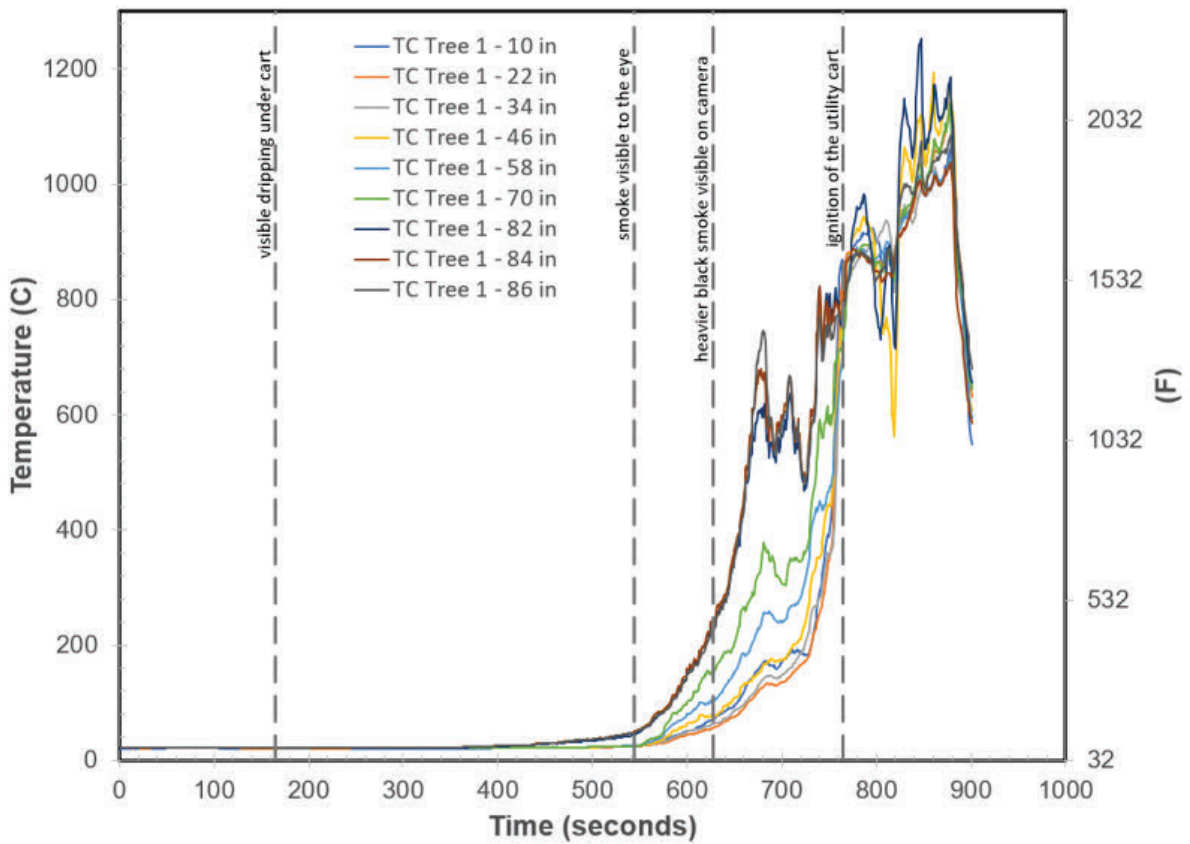


Figure 53: Phase 3, Test 7, Temperature versus time [5]

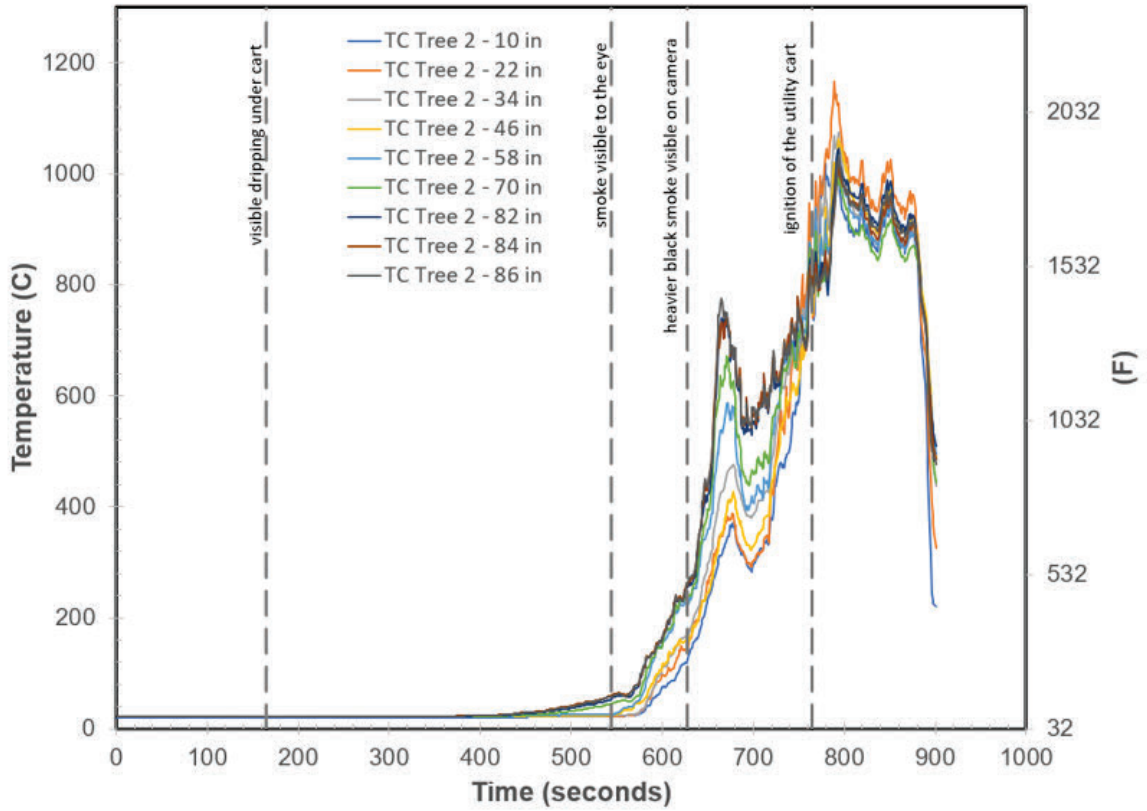


Figure 54: Phase 3, Test 7, Temperature versus time [5]



Figure 55: Phase 3, Test 5, (361122_1339878. JPG)



Figure 56: Phase 3, Test 5, post test damage (361122_1339928. JPG)