Acquisition Directorate
Research & Development Center

Report No. CG-D-02-16

Initial Burn Pan (JMTF) Testing Results

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Homeland Security

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16. Abstract (MAXIMUM 200 WORDS)

The goal of this series of tests, described in this report, was to re-establish the in-situ burn (ISB) capabilities at the Joint Maritime Test Facility (JMTF) with the intent to provide a test bed for future research and equipment development. The capability was originally established in 1998 to develop an American Society of Testing and Materials (ASTM) standard for fire-resistant boom. It had not been used for over 15 years and was almost completely destroyed when hurricane Katrina made landfall in August 2005. To achieve the goal to restore the facility, the USCG Research and Development Center (RDC), the Bureau of Safety and Environmental Enforcement (BSEE), and the US Naval Research Laboratory (NRL) assembled a team with the needed diverse experience covering full scale fire testing, in-situ burning and the spectrum of navigational aspects of performing these burns/functions at sea.

The burn pan was refurbished by repairing, re-leveling, plugging potential leaks and painting. A system to deliver fuel to the pan for testing was developed and installed. Sensors and video cameras connected to a data collection system were also installed and a test plan based on the ASTM standard was developed.

Three burns increasing in size were conducted lasting about 10 minutes, 35 minutes and 60 minutes respectively. Data was recorded using video, still cameras, thermocouples and air monitoring sensors. Support was supplied by the Gulf Strike Team (GST) and other partners including Sector Mobile, Station Dauphin Island and the Alabama Port Authority.

The burns were completed without any problems or mishaps. The information collected will be used to complete the refurbishment and develop test plans and operating procedures for future use of the facility to meet USCG and BSEE objectives.

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EXECUTIVE SUMMARY

The goal of the tests described in this report was to re-establish the in-situ burn (ISB) test capabilities at the Joint Maritime Test Facility (JMTF) with the intent to provide a test venue for future research and equipment development. The capability was originally established in 1998 to develop an American Society of Testing and Materials (ASTM) standard for fire-resistant boom. The burn pan had not been used for over 15 years and was almost completely destroyed when hurricane Katrina made landfall in August 2005. To achieve the goal to restore the burn pan, the USCG Research and development Center (RDC), the Bureau of Safety and Environmental Enforcement (BSEE), and the US Naval Research Laboratory (NRL) assembled a team with the needed diverse experience covering full scale fire testing, in-situ burning and the spectrum of navigational aspects of performing these burns/functions at sea. This study was funded in part by the U.S. Department of Interior, Bureau of Safety and Environmental Enforcement (BSEE) through Interagency Agreement E14PG00039 with the United States Coast Guard Research and Development Center.

The burn pan was refurbished by repairing, re-leveling, plugging potential leaks and painting. The area around the pan was cleared and an instrument/control station shed was installed. A system to deliver fuel to the pan for testing was also developed and installed. Sensors and video cameras connected to a data collection system were also installed and a test plan based on the ASTM standard was developed.

Three burns increasing in size were conducted lasting about 10 minutes, 35 minutes and 60 minutes respectively. Data was recorded using video, still cameras, thermocouples, heat flux gauges and air monitoring sensors. The data was in line with that collected during previous tests at the facility. Support was supplied by the Gulf Strike Team (GST) and other partners including Sector Mobile, Station Dauphin Island and the Alabama Port Authority.

The burns were completed without any problems or mishaps. The information collected will be used to complete the refurbishment and develop test plans and operating procedures for future use of the facility to meet USCG and BSEE requirements and objectives. This includes completing work on the wave maker which was not operational for this test.

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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

A	Amperes
ASTM	American Society of Testing and Materials
BP	British Petroleum
cm	centimeter
cfm	cubic feet per minute
cmm	cubic meters per minute
DAQ	Data Acquisition System
ft	feet
ft^2	square feet
gal	gallons
gpm	gallon per minute
GAR	General Assessment of Risk
GST	Gulf Strike Team
ICS	Incident Command Structure
in	inch
ISB	In-Situ Burning
JMTF	Joint Maritime Test Facility
kPa	kiloPascal
kW	kilowatts
kW/m^2	kilowatts per square meter
L	Liter
Lpm	Liter per minute
LSI	Little Sand Island
m	meter
m^2	square meters
mm	millimeters
mph	miles per hour
MRT	Medium Range Torch
NOAA	National Oceanic and Atmospheric Administration
psi	pounds per square inch
RDC	US Coast Guard Research and Development Center
SDS	Safety Data Sheets
NIST	National Institute of Standards Testing
NRL	Naval Research Laboratory
PM	Project Manager
PPE	Personal Protection Equipment
PVC	Polyvinylchloride
TC	Thermocouple
USCG	United States Coast Guard
V	Volts

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1 INTRODUCTION

In the 1990's, the National Institute of Standards Testing (NIST) in partnership with multiple other United States and Canadian agencies and commercial companies, conducted an extensive research program to assess the effectiveness of In Situ Burning (ISB) of oil as a response option to catastrophic oil spills. The focus of the testing was to measure the resulting air emissions, residual oil, and boom containment performance. During this initial assessment, NIST developed the capabilities to run mesoscale burn tests at the United States Coast Guard (USCG) Research and Development Center (RDC) Joint Maritime Test Facility (JMTF) in Mobile, AL (NIST, 2003). By 2003, both the USCG and Environment Canada had produced operational guides, provided standards for fire-resistant booms and igniting techniques needed to perform offshore burns.

However, these techniques had never been used on a reasonable scale during an actual response until the Deepwater Horizon spill in April, 2010. With the assistance of the local fishing community and commercial responders, the USCG and British Petroleum (BP) conducted over 400 offshore burns consuming an estimated 220,000-310,000 barrels of oil. Several of the burns lasted over 8 hours and the use of multiple task forces permitted simultaneous burning. This was the first full operational use of ISB. Many lessons were learned about the operations, equipment, and science; but questions still remained.

Several industry led groups were assembled to determine how to address ISB knowledge gaps that emerged from Deepwater Horizon. Some of the efforts include development of new manuals and guidelines sponsored by the American Petroleum Institute (API). However, additional research is still required to address outstanding technical issues as little has been done with respect to the equipment enhancements proposed.

1.1 Goal of the Tests

The goal of the tests described in this report was to re-establish the ISB test capabilities at the JMTF with the intent to provide a test venue for future research and equipment development. The burn pan had not been used for over 15 years and was almost completely destroyed when hurricane Katrina made landfall in August 2005. To achieve this goal, the USCG, BSEE, and the US Naval Research Laboratory (NRL) assembled a team with the needed, diverse experience covering full scale fire testing, in-situ burning and the spectrum of navigational aspects of performing these burns/functions at sea. The ISB Team consisted of NRL/Ex-USS *Shadwell* personnel; USCG personnel from the US Coast Guard Research and Development Center (RDC), JMTF, and Gulf Strike Team (GST); BSEE Oil Spill Response Research Personnel; and subcontractor support from Jensen Hughes Inc. This report is based on three documents that provided a test plan for these tests, the results of the tests and a third providing a proposed concept of operations (CONOPS) for executing future tests (Back et. al., 2015a, 2015b, 2016).

2 TEST SETUP

The ISB Team assembled the equipment required to conduct containment boom approval tests in accordance with ASTM F2152 on Little Sand Island (LSI) at the JMTF. The layout of the necessary systems and stations on LSI is shown in Figure 1. The burn pan, in the center of Figure 1, generally lies in a north-south orientation with north to the left of the figure.

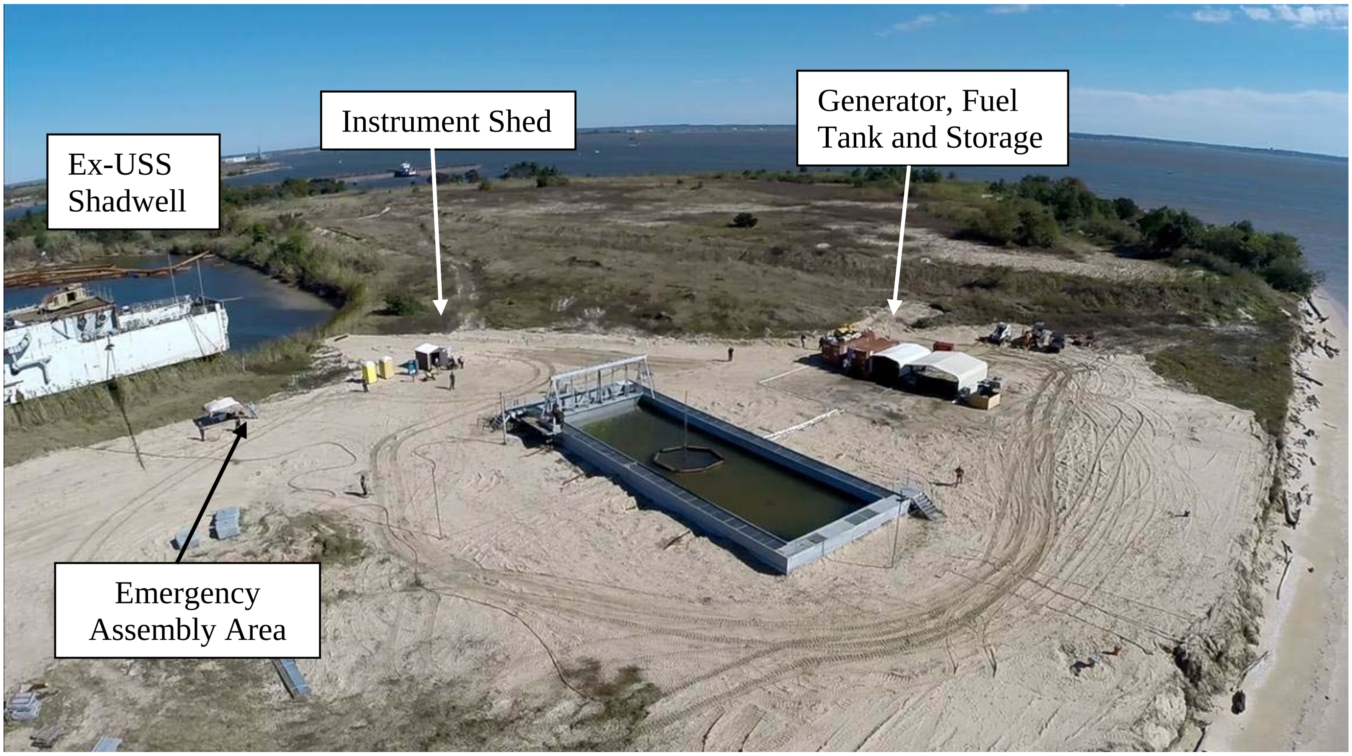

Figure 1. Aerial view of Little Sand Island.

2.1 Burn Pan

2.1.1 Initial Conditions

The burn pan was fabricated out of steel and installed in 1998 on Little Sand Island (Figure 2). The outer burn pan is approximately 33.0 m (108 ft) long, 11.6 m (38 ft) wide and 1.5 m (5 ft) deep. The 1.02 m (4 ft) wide trough separates the inner burn wall from the outer wall. The inner burn pan is approximately 30.5 m (100 ft) long, 9.2 m (30 ft) wide and 1.5 m (5 ft) deep. About 4.9 m (16 ft) of the north end of the burn pan is occupied by the wave generator which features a wave paddle suspended by a support structure 4.9 m (16 feet) above the tank floor (seen to the left in Figure 1 and to the right in Figure 2). The top of the trough is covered with deck grating and serves as a walkway around the top of the burn pan (Bitting 1999). Testing in Figure 2 shows a boom constrained from horizontal movement by several stanchions anchored to the bottom of the tank. It was instrumented with temperature and heat flux gauges. The last full test was in 1999. Figure 3 shows damage to the tank from hurricanes that flooded the island in 2005.

Figure 2. Wave tank (burn pan) with burn in progress.

Figure 3. Burn pan showing sand removed from base and disconnected pipes (left) and other damage (right).

2.1.2 Reconditioning/Repair

The ISB burn pan on LSI was re-leveled and repainted; and the surrounding ground cleared to prepare for this test. As mentioned above, the burn pan consists of a pan-in-a-pan design where the inner pan is the actual fire pan and the outer trough is filled with water to provide cooling of the fire pan walls. Figure 4 shows the interior of the refurbished burn pan. There are a number of piping interfaces that were originally installed on the burn pan to provide access for the various subsystems on LSI, such as fuel input and water draining. Since these subsystems were also destroyed by Katrina, the interfaces were sealed off during this test program. However, two new spool pieces were added during this refurbishment on the east side of the burn pan to provide access for the fuel pipe and instrumentation.

Figure 4. Burn Pan looking north towards wave generator.

2.2 Wave Generator

The hydraulic motor and reservoir were destroyed by Katrina and still need to be replaced. The paddle assembly and the hydraulic cylinder are shown in Figure 5. The original intent was to refurbish the wave generator and purchase a new hydraulic supply system for use during the demonstration. However, due to cost constraints, the hydraulic supply system was not purchased and thus the wave generator was not used during this test series.

Figure 5. Views of wave generator.

2.3 Burn Pan Water

During filling of the burn pan, a high volume submersible pump was placed on a small platform located between the Ex-USS *Shadwell* and LSI. The water used to fill the burn pan was drawn directly from Mobile Bay. The pump was connected to a 6.4 cm (2.5 in) fire hose that was placed in the burn pan. On completion of the test series, the effluent in the burn pan was removed by an approved waste handling organization in January, 2016. During testing, the tank was only filled to the 76 cm (about 2.5 foot) level.

2.4 Fuel System

The fuel system consisted of a single 5,678 liter (1,500 gal), double walled tank that was located on the east side of the burn pan and is shown in Figure 6. The fuel tank was equipped with an integral electric pump that was used to supply the fuel to the burn pan during the test. The fuel tank/pump was connected to the burn pan using 1 ½ inch PVC piping and fittings. The fuel piping had an estimated volume of 57 liters (15 gallons). The PVC piping close to the burn pan was wrapped with Fiberfrax to provide thermal protection during the burns.

Figure 6. Fuel supply tank.

A spool piece was welded to the burn pan to span the outer chamber and to provide a flanged fitting inside the burn pan. A separate piece made of steel was fabricated to go inside the burn pan, including a riser to allow the discharge of the fuel just below the water surface. A nozzle with six, 1.0 cm (0.38 in) diameter holes around the perimeter was installed on the riser to provide an even distribution of fuel below the water surface inside of the boom. The riser and fuel nozzle are shown in Figure 7; and the test configuration is shown in Figure 8.

Figure 7. View of fuel nozzle.

Figure 8. Location of boom with respect to fuel nozzle.

2.5 Containment Boom

The RDC purchased 30 m (100 ft) of American Fireboom MKII for this test. The American Fireboom MKII is approved per ASTM F2152 and was successfully tested during the first series of burns in 1999; and was used in ISB operations during the Deepwater Horizon spill. The boom construction is shown in Figure 9.

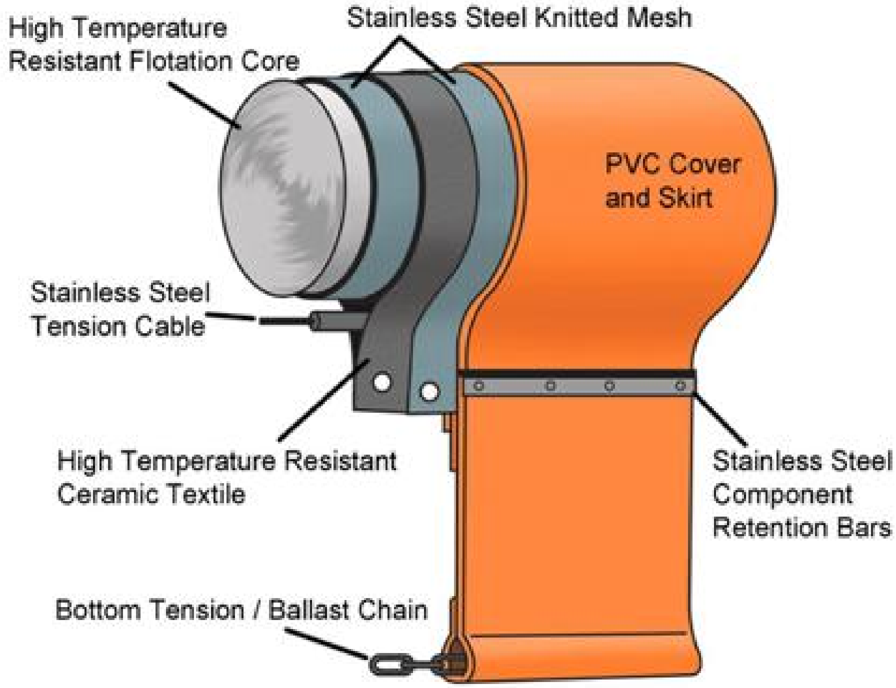

Figure 9. Cross-section of American Fireboom MKII (ELASTEC 2016).

The fires were ignited using a Medium Range Torch (MRT). The MRT has a range of about 15 m (50 ft) and discharges a solution comprised of diesel, gasoline, and napalm (Figure 10). The torch has a 19 liter (5 gal) capacity. The solution consists of 9.5 liters (2.5 gal) of diesel fuel, 9.5 liters (2.5 gal) of ethanol-free gasoline and l42 grams (5 ounces) of napalm as a thickening agent. The solution cylinder was pressurized to 5,516 kPa (800 psi) with CO_2.

Figure 10. Use of Medium Range Torch (MRT).

2.6 Instrumentation and Photogrophy

The data acquisition system and video Digital Video Recorders (DVR) were located in the Instrumentation Shed on the north side of the burn pan. The Instrumentation Shed also served as the Control Room for these tests.

2.6.1 Data Acquisition System (DAQ)

A DAQ was installed to monitor and record a range of parameters during these tests including: the temperature of the water, the temperature directly above the fire, the temperature of the boom, and the exposures as a function of distance away from the fire. The system consisted of a patch panel with 48 inputs (32 thermocouples and 16 analog), a number of multiplexer cards and a laptop computer to monitor and record the data. The instruments were scanned once every second (1 Hz) and saved to a file using National Instruments Co. software titled "LabVIEW."

2.6.1.1 Temperature

Thermocouples (Inconel sheathed Type K) were installed to measure the plume temperature directly above the fire, the temperature of the water in the burn pan at various depths and the gas/flame temperature adjacent to the boom. A thermocouple pole was located in the center of the boomed area to measure the fire/plume temperature at this location. Six thermocouples were installed on the pole at 1.2, 1.8, 2.4, 3.0, 3.6 and 4.2 m (4, 6, 8, 10, 12 and 14 ft) above the water surface. Additionally, three thermocouples were installed on the pole below the water surface at 5, 10 and 15 cm (2, 4 and 6 inches). Five thermocouples were installed on the containment boom to measure the gas/flame temperature adjacent to the boom during the tests. One thermocouple was installed at each of the four compass headings on the inside of the boom: north, south, east and west and one thermocouple was installed downwind on the outside of the boom.

2.6.1.2 Radiant/Total Heat Flux Exposures

Schmidt-Bolter total heat flux transducers (200 kW/m^2 full scale range) were installed on the south and west sides of the burn pan approximately 18.3 m (60 ft) from the center of the fire and about 3.0 m (10 ft) above the top edge of the burn pan. These measurements were used to quantify the exposures (primarily radiative) produced by the fire as a function of direction and distance from the flame.

2.6.2 Fuel Rate

The fuel pump installed on the fuel tank was similar to that used at a commercial gas station. The quantity of fuel discharged was displayed on the front of the pump. During the test, the pump operator manually recorded the amount of fuel discharged at one minute time intervals to calculate the fuel flow rate during the test. The pump discharge rate was calculated to be 85.2 Lpm (22.5 gpm).

The first test (static burn of 378 liters (100 gallons) of diesel), was used to calculate the fuel regression based on the fuel depth prior to the fire and the fire burn time. At full involvement, the fire consumed about 72 Lpm (19 gpm) of diesel fuel which corresponds to a fuel regression rate of about 5 mm/min (0.2 in/min). Based on this, the fuel rate used for the second two burns was 83 Lpm (22 gpm).

2.6.3 Air Quality Measurements

The USCG Gulf Strike Team (GST) deployed portable air monitoring equipment to support the Special Monitoring for Alternative Response Technologies (SMART) protocol. The GST set up two atmospheric sampling stations on LSI as well as at several external and strategic locations at points off the island. There were at least two particulate monitors installed on LSI during each test. These were typically installed about 30.5 m (100 ft) downwind of the burn pan (i.e., south side of the island). Additional sampling equipment stations were placed at the Coal Plant across the shipping channel and on the Causeway toward the center of town. During the demonstration burn (Test 3), a sampling device was placed on a fireboat located in the shipping channel downwind of the island.

During the original ISB tests conducted on LSI in the 1990's, elaborate measures were taken to measure the gas concentrations in the plume and collect particles to estimate smoke production/soot yield. Neither of these advanced measurements were made during this test series; but can be replicated during future tests.

2.6.4 Weather Measurements

Acceptable weather conditions for the burn tests/demonstration were verified the morning of each test via a phone conference with a National Oceanic and Atmospheric Administration (NOAA) representative prior to the test team departing for LSI. Acceptable conditions were based primarily on wind direction and speed. Specifically, acceptable wind directions are 240^o SW to 050^o NE (degrees true, direction) with speeds less than 15 knots.

The GST also installed a portable weather station (WEATHERPAK MTR manufactured by Coastal Environmental Systems) on LSI during these tests that recorded wind and temperature. The measurement location was approximately 9.1 m (30 ft) east of the Instrumentation Shed during Tests 1 and 2 and on the beach adjacent to the shipping channel during Test 3. The measurements were displayed in the Instrumentation Shed and were manually recorded during each test.

2.6.5 Video and Photography

Both video and still photography (digital) were used to document these tests. Still photos were taken of the test setup prior to the start of each test and upon completion of each test. A number of still photos were also taken during each test. Each test was videotaped using at least five standard video cameras: one located on each of the four sides of the burn pan and one located high on the Ex-USS *Shadwell*. There were also a number of GoPro cameras (3-4) that were positioned to observe specific locations around the test area. A remote control drone equipped with a GoPro camera was also used to video the third test. All recorded video and still photographs were saved to the electronic archive that was provided to the USCG at the end of the test program.

3 TEST MANNING AND PROCEDURES

3.1 Test Personnel

During these tests, the RDC deployed an Incident Command Structure (ICS) and an Incident Action Plan (IAP) developed by GST. There were two primary teams that participated in the conduct of these tests: the NRL Fire Test Team and the USCG Project/Safety Team. The NRL Fire Test Team consisted of the Test

Director, one Safety Officer, two Firefighters, a fuel system operator, two data acquisition/video technicians and one subject matter expert (to provide oversight and document each test). The USCG Project/Safety Team consisted of three Safety Officers, eight air sampling specialists, several observers/recorders and a project manager. Two GST air sampling specialists performed dual roles as EMTs on both LSI and the Ex-USS *Shadwell*.

3.2 Test Procedures

Test procedures developed from earlier testing were modified to address the current test setup on LSI (Bitting 1999 and Evans et. al. 2001). Detailed test procedures can be found in the approved/published test plan (Back et. al., 2015a). A Concept of Operations (CONOPS) document for conducting future tests has been developed and was published as a separate document (Back et. al. 2016).

4 TEST DESCRIPTION AND RESULTS

Three tests were conducted in a still water environment (i.e., no wave generator). Test 1 consisted of a static burn of 378 liters (100 gallons) of diesel fuel. Test 2 consisted of a 30 plus minute flowing fuel fire with the fuel being supplied to the boomed area from a nozzle located below the water surface. Test 3 consisted of a 60 minute flowing fuel fire as required in ASTM F2152. The three tests were conducted on the days shown in Table 1.

Table 1. Test schedule.

Test #	Description	Date
1	Static pool fire	Nov. 13
2	Medium duration flowing fuel fire (30 minutes)	Nov. 14
3	Long duration flowing fuel fire (60 minutes)	Nov. 19

4.1 Test 1 – Static Pool Fire

Test 1 was conducted to verify that all test equipment was operating properly; and to begin the refinement of the procedures for the latter tests. The fuel was discharged into the boomed area using the flowing fuel system. Approximately 10 seconds after ignition, the fuel surface became fully involved and the vinyl boom cover ignited and began to burn. The fire burned at full involvement for just over five minutes (5:05).

The wind speed and direction measured on the island during the test by the GST station was from the north at 6-7 mph. The wind speed recorded by the National Weather Service was almost double coming from the north at 13 mph. The weather station appeared to be located in the wind-shadow produced by the Ex-USS *Shadwell*.

The wind pushed the fire plume toward the south at an angle of roughly 30 degrees above the horizontal (Figure 11). This increased the heat exposure on the south side of the boom and reduced the exposure on the north side of the boom. The low plume trajectory kept the flames and hot gases from impinging directly on the thermocouple pole causing it to measure lower temperatures than originally anticipated (Figure 12). Direct flame impingement would produce temperatures in excess of 500^{o}C as compared to the 50^{o}C – 300^{o}C measured during this test.

Figure 11. Full involvement burn.

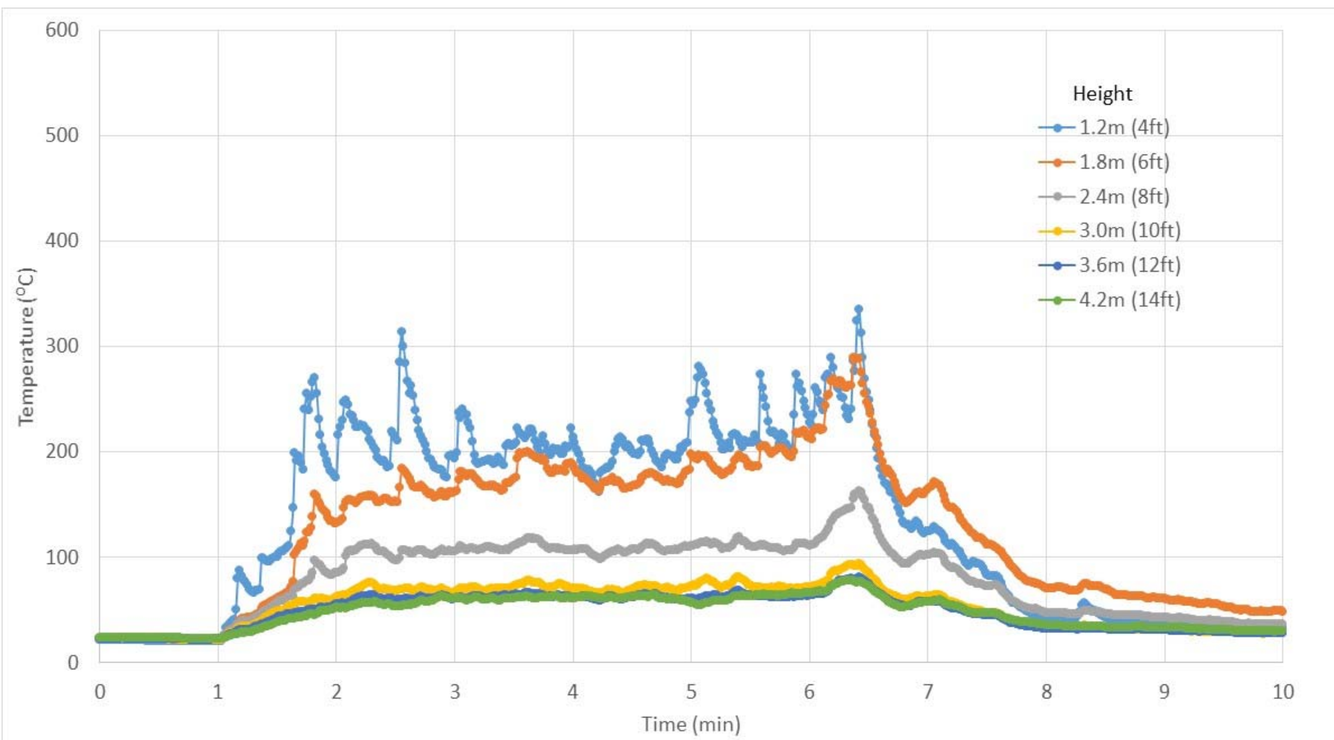

Figure 12. Test 1 - Data from thermocouple pole.

The boom successfully contained the fuel for the duration of the test. The temperatures measured around the perimeter of the boom ranged from 600 - 850°C during full involvement. The boom temperatures are shown in Figure 13. Note that the north and south temperatures had 200 degree temperature shifts during the short burn time. The underwater thermocouples show a 10 degree increase until the last of the oil was burning near the end of the test (Figure 14).

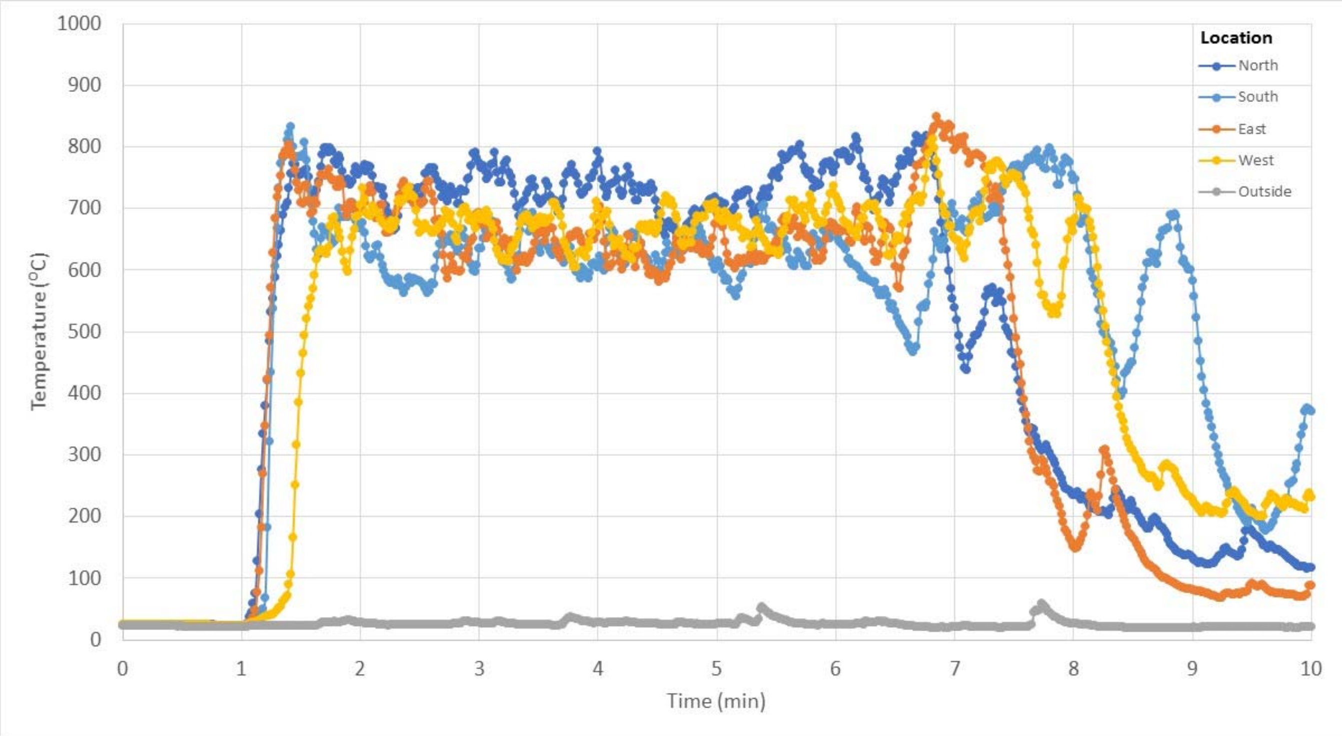

Figure 13. Test 1 - Data from boom thermocouples.

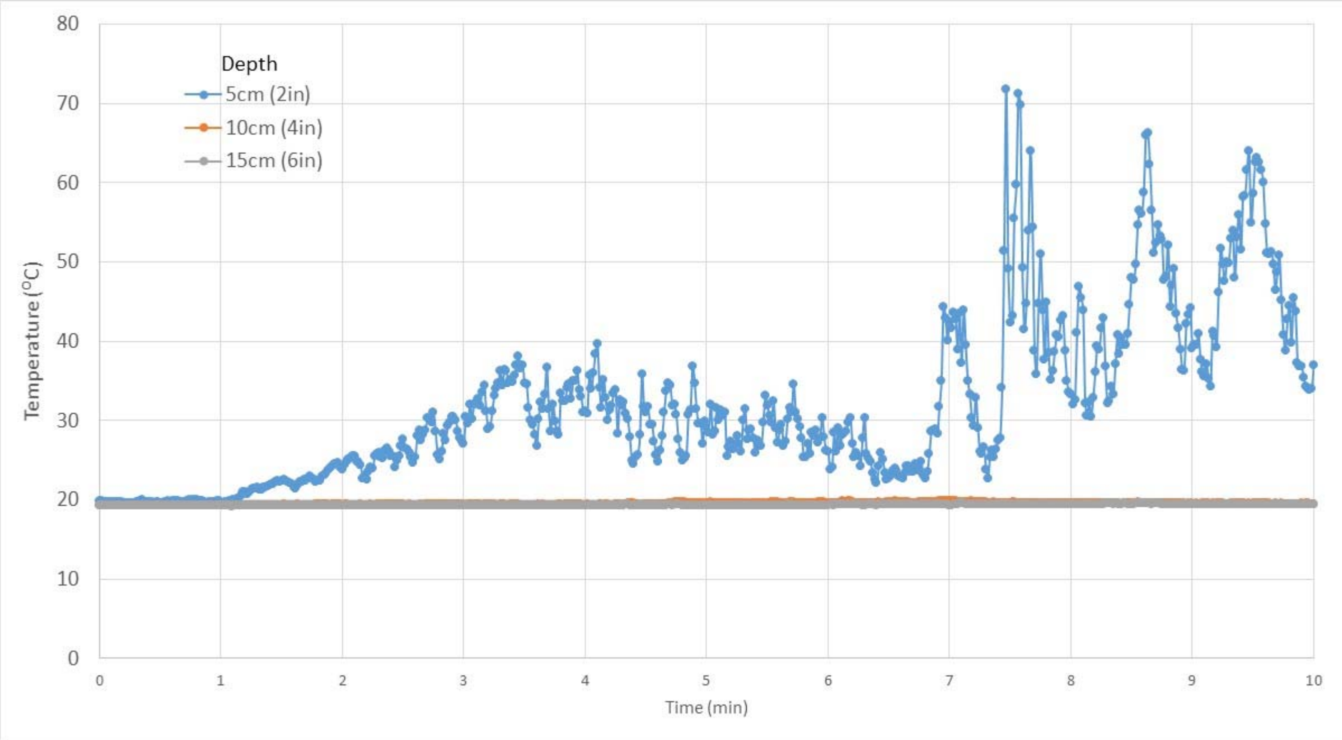

Figure 14. Test 1 - Data from underwater thermocouples.

A post-test inspection of the boom revealed that all of the yellow vinyl cover on the south end of the boom had been consumed by the fire leaving only the material below the waterline intact. The north end of the boom experienced less damage with most of the yellow vinyl freeboard on the north side still fairly intact. A photograph showing the boom after the test is provided as Figure 15.

Figure 15. Test 1 - Post-test boom condition.

4.2 Test 2 – Medium Duration Flowing Fuel Fire

Test 2 consisted of an approximately 30 minutes flowing fuel fire (approximately 83 Lpm (22 gpm)) in a still water environment. This test was conducted to verify that all test equipment including the fuel discharge system was operating properly; and to determine the fuel burning/consumption rate during the flowing fuel fire scenario.

The wind speed and direction were almost identical for Tests 1 and 2. The wind speed and direction measured on the island during the test was from the north at 6-7 mph and that recorded by the National Weather Service was almost double coming from the north-northeast at 12 mph. As with Test 1, the Ex-USS *Shadwell* appeared to have blocked the wind in the area near the weather station.

The winds caused the smoke to hug the ground/water preventing it from rising high into the atmosphere as shown in Figure 16. The low plume trajectory kept the flames and hot gases from impinging directly on the thermocouple pole causing it again to read lower temperatures than originally anticipated (75°C – 350°C as opposed to what could have been greater than 500°C). The thermocouple pole temperatures are shown in Figure 17. These temperatures are slightly higher than the first test due to the continuous addition of fuel.

Figure 16. Test 2 - View from ex-USS Shadwell.

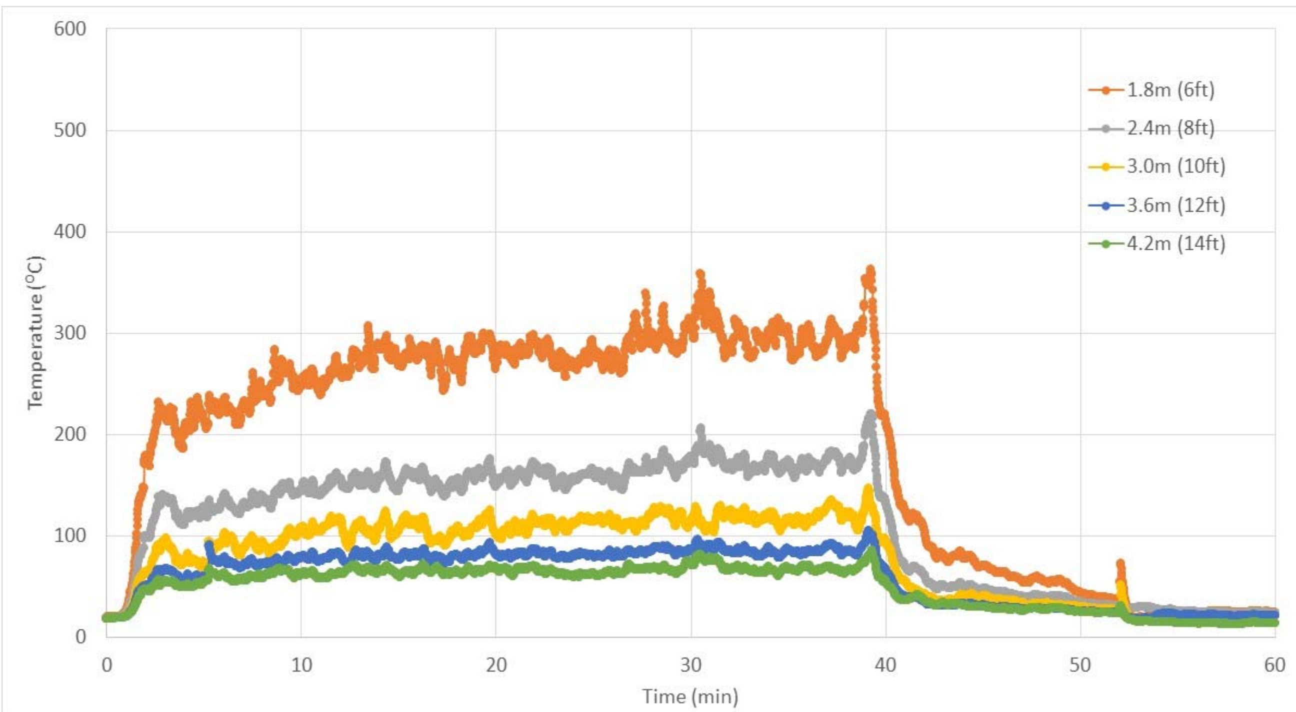

Figure 17. Test 2 - Data from thermcouple pole.

The fuel flow was secured after a total of 2,650 liters (700 gallons) of diesel had been pumped into the burn pan (341 liters prior to ignition and 2,309 liters during the flowing fuel period (90 gallons prior to ignition and 610 gallons during the flowing fuel period)). The flowing fuel period lasted for approximately 28 minutes. The boom again successfully contained the fuel for the duration of the test. The temperatures measured around the perimeter of the boom ranged from 500 - 850^{o}C during full involvement; but did not fluctuate as much as the first test (Figure 18). A post-test inspection of the boom revealed that only a limited amount of thermal damage occurred during this test as the boom looked almost identical to the pre-test photo. The underwater thermocouples showed little increase until the last couple of minutes of the burn, similar to Test 1.

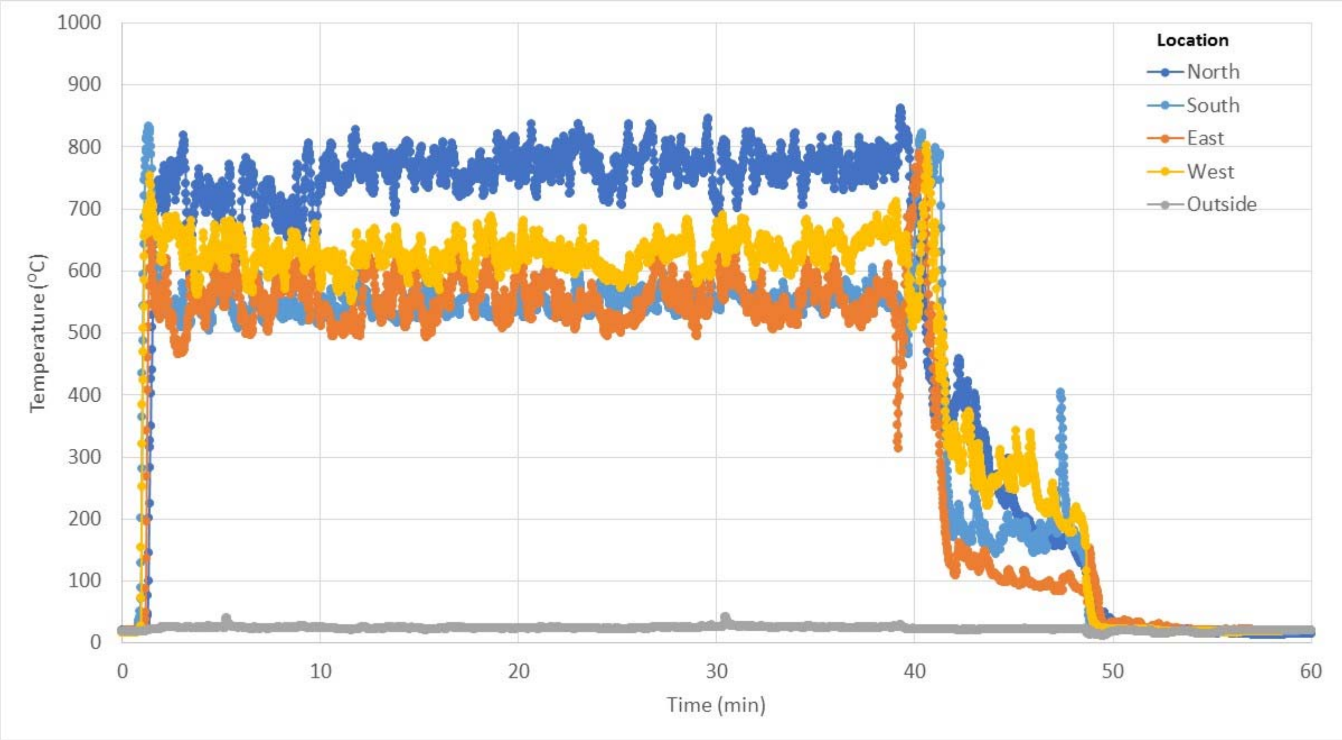

Figure 18. Test 2 - Data from boom thermocouples.

4.3 Test 3 – Long Duration Flowing Fuel Fire

The final test consisted of a 60 minute flowing fuel fire in a still water environment using the same boom. This test was intended to validate the ability to safely and accurately conduct ASTM F2152 testing. At the start of the test, the fuel system was activated for four minutes and discharged 341 liters (90 gallons) of diesel into the boomed area. The fuel flow was secured after a total of 4,353 liters (1,150 gallons) of fuel had been pumped into the burn pan 4,012 liters (1,060 gallons) during the flowing fuel period. The flowing fuel period lasted for about 48 minutes.

The fire burned at full involvement for about 63 minutes. During the full involvement period, the fire consumed fuel at a rate of 68.1 Lpm (18 gpm). As the fire began to burnout, a crackling sound was heard that was the boiling of some of the water on the surface as during the previous tests. This period lasted for about 3 minutes. By 66 minutes after ignition, all of the fuel in the boomed area had been consumed and the only visible burning was located on the boom itself.

Similar to the previous tests, the higher wind speed pushed the fire plume toward the south- southwest at an angle of roughly 30 degrees above the horizontal. The winds caused the smoke to hug the ground/water preventing it from rising high into the atmosphere, but not as much as the previous tests as shown in Figure 19. The low plume trajectory kept the flames and hot gases from impinging directly on the thermocouple pole causing it again to read lower temperatures than originally anticipated as shown in Figure 20. The values increase slightly as the test goes on, similar to Test 2.

Figure 19. Test 3 - View of smoke plume.

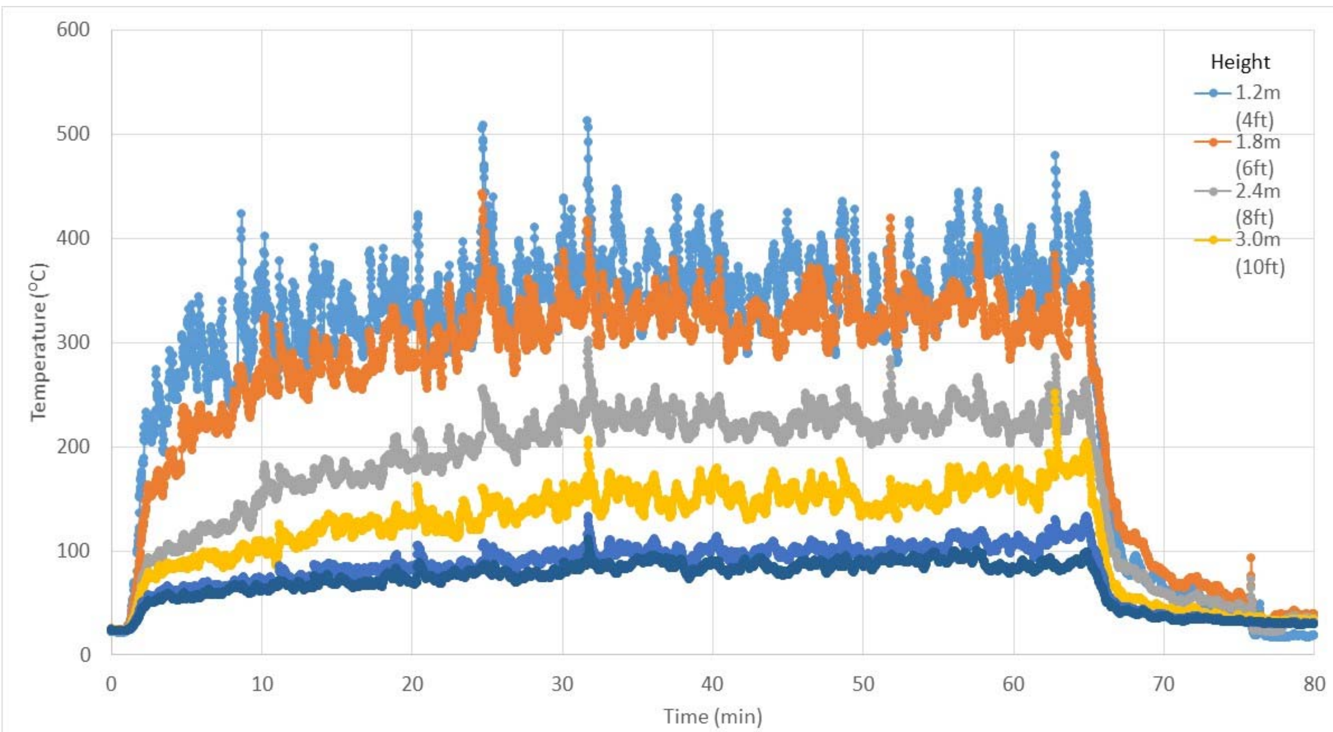

Figure 20. Test 3 - Data from thermocouple pole

Test 3 was the first test where the total heat flux to a target was accurately measured due to a technical glitch that prevented these measurements during Tests 1 and 2. The total heat flux on the west side of the burn pan averaged about 1.25 kW/m^2 during full involvement (Figure 21). This flux was entirely radiation since the transducer was located away from the burn pan in ambient air (i.e., there was no convective/hot gas component). The total heat flux on the south side of the burn pan averaged about 0.75 kW/m^2 with spikes as high as 2-4 kW/m^2 during full involvement. The average value was primarily radiation which was less than the west side transducer due to smoke obscuration. The spikes were driven by convection as the plume was sporadically blown toward the transducer. These values are a little lower than those measured in the previous tests in the 1990s; because the sensors were located farther away from the fire.

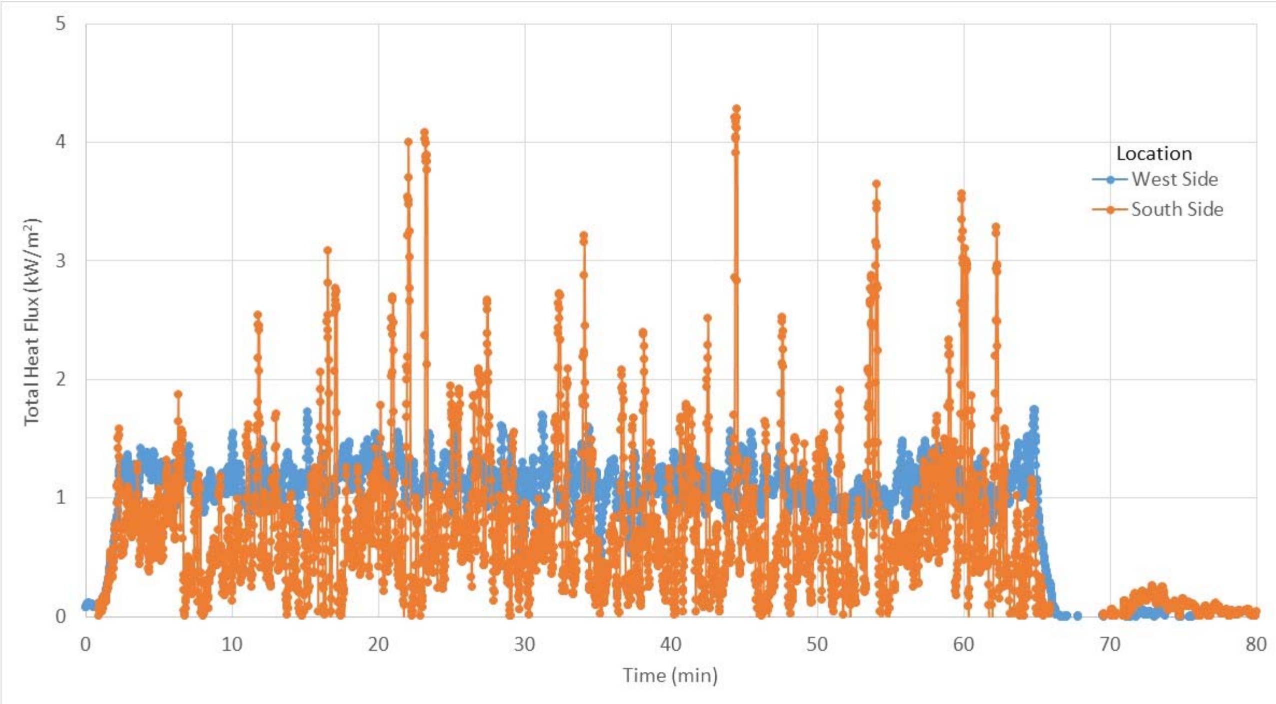

Figure 21. Test 3 - Heat flux data.

As with the previous tests, the boom successfully contained the fuel for the duration of the test. The temperatures measured around the perimeter of the boom ranged from about 600 - 850°C during full involvement. The boom temperatures are shown in Figure 22.

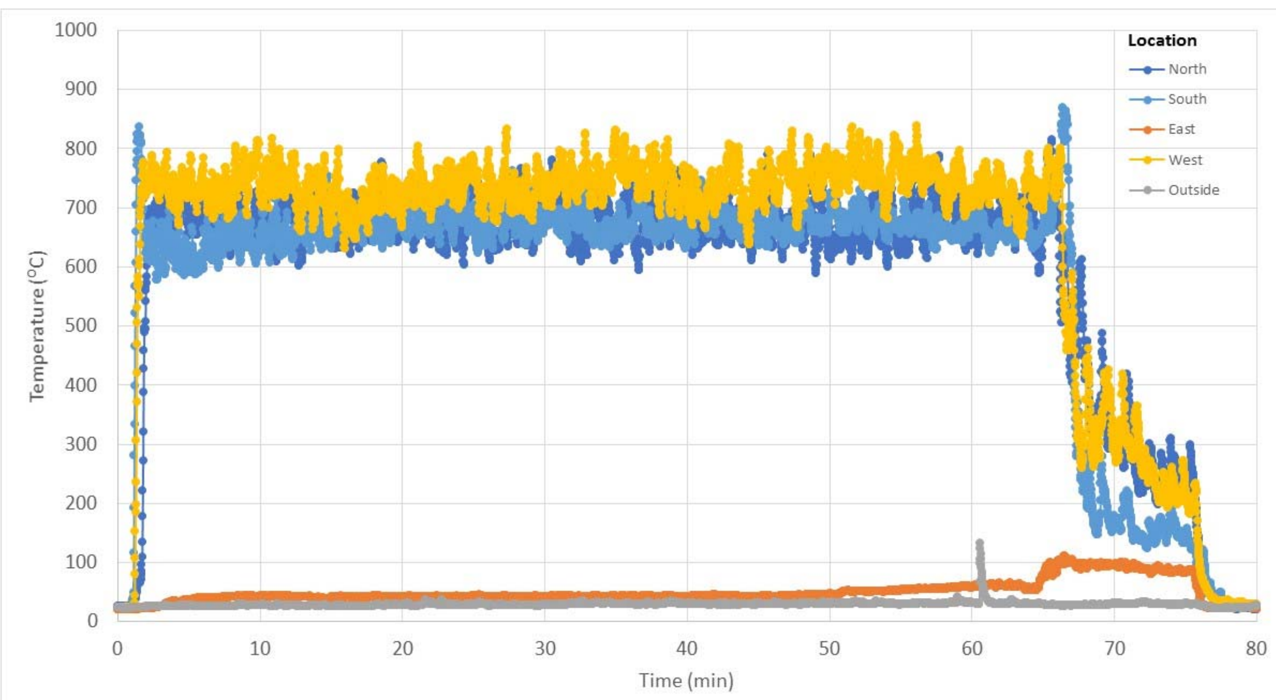

Figure 22. Test 3 - Data from boom thermocouples.

The water temperature at 5 cm (2 in) below the fuel surface slowly increased from 20°C to 23°C during the test (Figure 23). The minimal temperature rise was attributed to the constant supply of relatively cool fuel into the boomed area and the mixing created by the fuel flow. This is consistent with that observed during Test 2; suggesting that the water depth was similar between the two tests. After the test was complete, the water discharged by the Firefighting Party into the boomed area (during suppression of the boom itself) produced temperature spikes as high as 35°C, 5 cm (2 in) below the water surface. This was attributed to the mixing produced by the hose stream of the hot water near the surface.

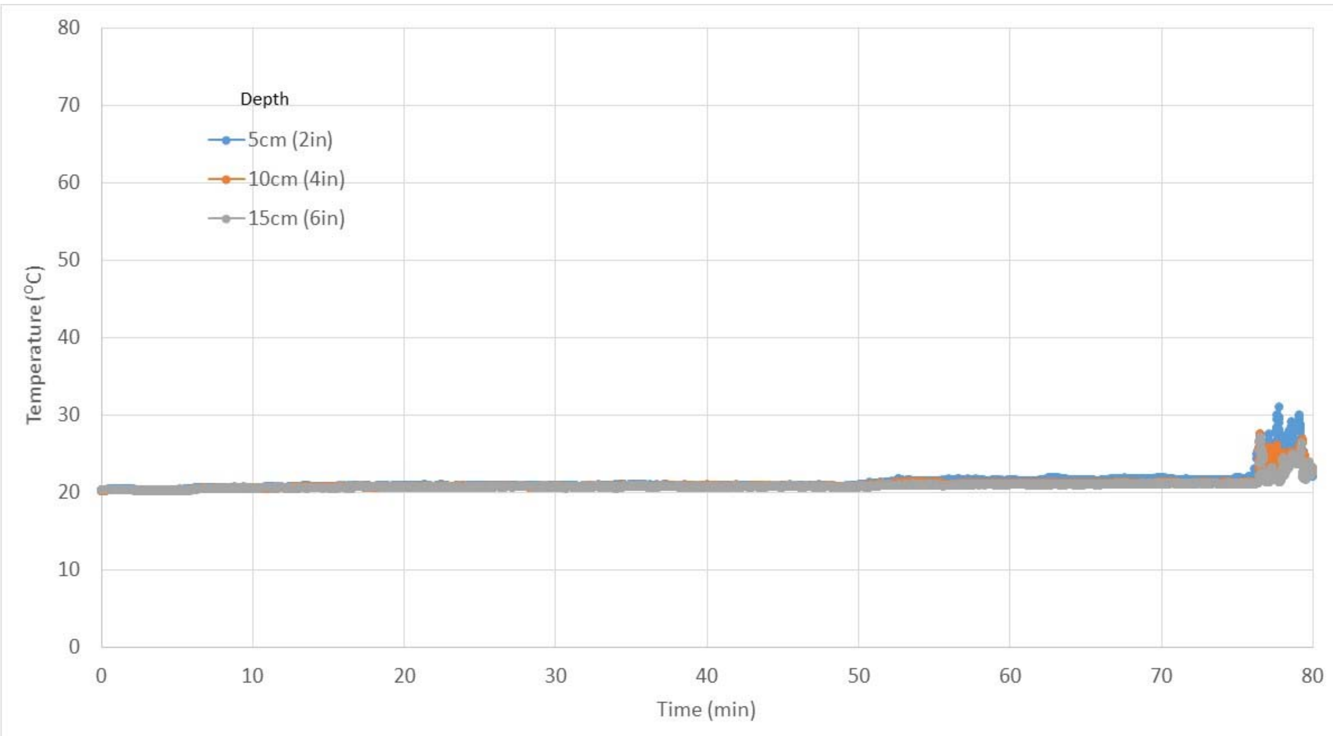

Figure 23. Test 3 - Data from underwater thermocouples.

5 TEST OBSERVATIONS

In general, this effort was considered a success. All of the test objectives to identify the issues that need to be addressed to make the burn pan operational were accomplished without any mishaps or injuries. This was a unique test that was used to flush out any issues that must be addressed before moving forward. Extra support from the Gulf Strike Team and other local stakeholders was crucial in completing this initial set of burns.

The test plan was also unique to this test; and was intended to be flexible in order to incorporate lessons learned between burns. The lack of computer and printer access for the test plan (over 70 pages), as well as the large Incident Action Plan (IAP) (40 pages), made it difficult to get the information out to all participants in real-time. The methodical approach taken by the National Research Laboratory (NRL) subcontractor (Jensen Hughes) was instrumental in ensuring safety.

Communications during the testing were also developed and changed between the multiple burns as the test team, safety team and GST identified the need for separate channels; and provided enough radios to maintain contact within the teams. Generally, the communications and safety aspects worked well.

Use of a standard real-world ISB ignition practice, that has less risk than the use of the Medium Range Torch (MRT), would provide the added benefit of training and evaluating actual field procedures.

Processing of the waste water took longer than anticipated and was not completed until the end of January. The original estimates did not take into account the minimum charges for personnel, a barge and an accompanied tugboat that was needed to transport people and equipment to LSI; and the final load of water off of LSI. Heavy rain during the interim time also increased the disposal amount.

The General Assessment of Risk (GAR) process was used in the morning planning meeting with the principle participants. A second safety check was conducted on the island by the NRL test director just before initiating the burn process. Safety issues that need to be addressed for future efforts include the assignments of the safety team and emergency procedures.

The public affairs support from RDC and the Sector was exceptional. During the final test, the Sector escorted a local film crew to view the burn at locations on the mainland manned by GST. A more proactive public affairs stance may be required in the future, with more active participation from the port authority.

6 LESSONS LEARNED

Fuel purchase and its loading into the storage tank on the island were problematic. The fuel will need to be procured further in advance; and the process to get it to the LSI may need to be revised to ensure CG, state and federal regulations are met. This procedure will be crucial for crude oil transport and use in the future.

Flexibility and contingency planning during the test week need to be emphasized. When the weather forecast for the second week appeared to preclude any testing for several days, the second test was moved forward which resulted in testing over a weekend. After business hours telephone numbers and/or e-mail addresses were not available for a couple of the stakeholders, so they could not be notified outside of regular business hours of last minute changes.

Securing any test measurement system to the burn pan does not permit any modifications of the equipment once the tank is filled. This was especially problematic when the water level changed due to some minor leakage and refill of the burn pan, and the draft of the boom could not be adjusted. This will be even more problematic if oil has already been put into the water, creating an additional personnel hazard.

There will need to be better methods to identify and mark hazard zones. The carports and storage area are currently in the smoke zone; and the heat from the fire could be felt from that area. While no one was injured, some miscommunication at the end of the second burn resulted in a couple of observers prematurely entering the hazard zone without the entire safety team being notified. The test termination process was revised for the last burn to alleviate this problem.

Test organization/management and use of the Incident Command System (ICS) needs better clarification, as individuals were identified but a rigorous sign in and out process was not initiated. It is not clear if a strict ICS is needed for future burns; but most of the processes and procedures may still need to be maintained.

7 RECOMMENDATIONS

This project has identified a number of modifications in equipment, policies and procedures that need to be changed or developed if CG-MER, BSEE and RDC decide that this capability is worthwhile to build up to support both BSEE and USCG objectives. To ensure maximum potential use, all changes should be flexible enough to handle various styles and types of testing; and reflect good practice in accordance to CG policy and procedures. The process and procedures used during the testing generally worked well; but will need refinements for future testing. They need to address the issues when performing the standard ASTM test; but should be broad enough to handle any type of test configuration. Tasks and issues that need to be addressed are described below and funding and/or labor hours will be sought within RDC to complete these actions:

A revised test plan should address:

- Processes and procedures when there is a deviation from the original schedule.
- Develop a test observer policy.
- In conjunction with the safety plan, develop participant training requirements for RDC, NRL and visiting participants (e.g. HAZWOPER, EMT, etc.).
- .
- Develop a draft Incident Action Plan that details the minimum requirements.

A better defined safety plan is needed that includes all aspects on LSI.

- Smoke and safety zones need to be better defined and marked, such as the use of stakes and caution tape.
- More operationally realistic ignition methods should be identified.
- Identify required participants and optional participants, so that outside support can be coordinated (e.g. GST, Sector, CG Patrol vessel, etc.).
- Develop better emergency shut-down procedures. The proposed process currently takes too long as the fuel is turned off; but could continue burning for 10-15 minutes. A preferable method may be to open any containment area and let the oil run out; which will cause it to thin out and extinguish the fire.
- Identify specific PPE for all participants based on assignments.
- Determine conditions where personnel can enter the water in the burn pan in an emergency; and what PPE is required.
- Identify processes and procedures that could permit burning; if some support, such as GST and the Sector, were not available.

The grates around the burn pan walkway were a safety hazard and need to be secured in a proper manner. Those adjacent to the burn flexed due to the wall distorting from the heat during the burn. Any method of attachment needs to be flexible to permit grate movement.

The stationery tank (red) and the trailerable tank (yellow) worked well in that they had integrated pumps with them; but they may not meet general fuel transfer requirements for fixed connections (e.g. Camlok type) and should not use open tops for loading. Consider the use of hoses that can be rolled up and emptied.

At the end of each test sequence, a better closeout procedure is needed for residual fuel. A specific DECON procedure for the end of each test sequence is needed to ensure no fuel remains in the pipe system. At the end of a test sequence, specific procedures are also needed for handling any residual fuel in the storage tanks as well.

A maintenance and operation plan for the burn pan is needed.

Other recommended upgrades and evaluations include:

- Consider acquiring a weather station for the island (potentially mounted on Ex-USS Shadwell) in lieu of relying on GST.
- Complete the wave generator installation.
- Determine how to mothball/store LSI equipment for extended storage times; and LSI equipment securing procedures for emergencies, such as hurricanes.
- Identify a cost effective method to decontaminate test equipment and the burn pan; and properly dispose any waste water.
- Complete a revised Environmental Assessment (EA) as needed to ensure no changes have occurred.

To develop this facility as a national asset, RDC will pursue internal and external funding to prepare the site for safe evaluation of ISB equipment and procedures. The facility will eventually be made available to outside researchers

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