Test Report

THOR^{SM} Drum Pyrolysis Demonstration

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SUBMITTED BY

THOR Treatment Technologies

TO

Washington TRU Solutions, LLC
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1.0 Executive Summary

In the first quarter of 2004, THOR Treatment Technologies, LLC (TTT) conducted a demonstration test of its THOR℠ pyrolysis system under contract to Washington TRU Solutions, LLC (WTS). Funding for this test was jointly provided by WTS, Westinghouse Savannah River Company (WSRC), and TTT. This Test Report and the Thermal Performance Report describe the results of the demonstration testing and are submitted to WSRC with a copy to WTS.

As the Management and Operations contractor for the Department of Energy's (DOE) Waste Isolation Pilot Plant (WIPP), WTS had identified the THOR℠ pyrolysis system as a potential solution to multiple TRU waste shipping and disposal problems. The specific TRU waste shipping and disposal problems of concern are:

TRU Waste Shipping and Disposal Problems

40% of TRU waste contains prohibited items

- **free liquids**
- **aerosol cans**
- **sealed containers**

Disposal options for 10 to 100nCi/g waste is limited

Shipping high-wattage waste containing organics is problematic because it generates hydrogen gas

- Approximately 40% of TRU waste in the complex contains prohibited items, such as free liquids, aerosol cans, and sealed containers greater than 4 liters. Currently, prohibited items are removed by sorting the waste in a glove box, separating out the prohibited items, and repackaging the waste. This approach is costly, time consuming, and increases the risk of worker exposure. THOR℠ is seen as a potential solution because it evaporates liquids and breaches both sealed containers and aerosol cans without removing waste contents from its original drum.

- Waste between 10–100 nCi/g with hazardous constituents is problematic because its Curie content is too high to be disposed of as low-level waste, but cannot be classified as TRU waste (which by definition is >100nCi/g). THOR℠ is seen as a potential solution to this problem because the pyrolysis process reduces the mass of the waste. By reducing the mass, the Curie concentration of the waste is increased such that the pyrolyzed waste can potentially increase to >100nCi/g. Whereas the current practice of "upblending" increases the total volume of waste disposed of at WIPP, using THOR℠ to treat this waste would decrease the total volume of waste disposed of at WIPP, as pyrolysis can reduce organic volume from 70–90% depending on the organic content.

- High-wattage waste (Pu-238 and high-wattage Pu-239) is problematic because radiolysis of organics by these high-wattage wastes produces hydrogen gas, which prohibits shipment of the waste. There is no current solution that will remove organics from these waste streams. THOR℠ is seen as a potential solution for high wattage waste because the pyrolysis process destroys organics, and the resultant pyrolyzed waste stream is an inert, inorganic carbon char and ash. The pyrolyzed waste stream would generate no hydrogen gas because it would not contain any liquids or organics.

In an effort to develop alternative solutions for these problematic wastes, WTS placed a contract with TTT to conduct a demonstration test of its pyrolysis system using drums of simulated TRU waste. Specifically, the THOR^{SM} pyrolysis system was to demonstrate its ability to:

- Remove the following prohibited items:
  - Remove free liquids
  - Breach sealed containers >4 liters
  - Breach aerosol cans

- Provide volume reduction
  - Weight reduction was to be measured
  - Volume reduction was to be estimated

- Qualitatively demonstrate in-drum criticality and contamination control
  - Qualitatively demonstrate that airborne particles are retained in a drum or in an overpack containment around the drum during treatment

- Provide efficient heat-up and residence times
  - Using temperature measurements, hydrocarbon gas analysis of the pyrolyzer off-gas, and visual examination, provide the following:
    - Report heat-up and residence times needed to remove free liquids and VOCs
    - Report heat-up times and residence times needed to remove organics
    - Provide an analytical thermal model to predict heat-up and cool down performance for drums of varying weight and composition.

The THOR^{SM} demonstration testing was performed in January–February 2004 at the George Westinghouse Technology Park in Pittsburgh, PA. A total of 10 drums of simulated TRU waste were pyrolyzed in the THOR^{SM} test pyrolyzer (the test equipment is described in Section 2.0 of this Test Report). The simulated debris waste was bagged and loaded into 55-gallon drums with liners in a manner that is very similar to the loading of actual TRU waste. Test operations were conducted under the direct supervision of TTT's Chief Engineer, and post-test inspection was conducted in accordance with the WTS-approved Test Plan. (Section 3.0 of this Test Report provides a detailed description of the drum assembly, test operations, and post-pyrolysis inspection.)

The THOR℠ test pyrolyzer performed flawlessly "out-of-the-box," as no operational problems were encountered—in fact, the pyrolysis system had no check-out, start-up, or operations problems.

THOR℠ Drum Pyrolysis Achieved All Test Objectives

All free liquids were removed

All sealed containers were breached

All aerosol cans were breached

Organic contents volume reduced 70-90%

Drum overpack with filter contained airborne particles

The demonstration testing was completely successful, as all test objectives were met:

- All prohibited items were removed from drums:
  - All free liquids were removed
  - All sealed containers were breached
  - All aerosol cans were breached
- Based on visual inspections, the organic volume of drum content was reduced by 70–90%, depending on the organic content. For example, if the original volume of waste were 10 cubic feet, and treatment produced a 90% reduction, then the volume of the post-pyrolysis residue would be only 1 cubic foot.
- The THOR℠ 85-gallon overpack with an integral filter provided containment and criticality control, as airborne particles were retained in the overpack.

The detailed description of the test results for each drum is provided in Section 4.0 of this Test Report.

The thermal performance of the test pyrolyzer is provided in a separate deliverable entitled Thermal Performance Report. This deliverable provides heat-up and residence times for all drums tested. It also provides an evaluation of the temperature and off-gas data that provides evidence that organics are destroyed and have been volatized. Finally, this document provides a thermal model that predicts residence and cooldown time for drums of varying weight and composition.

For a description of the pyrolysis chemistry, one can read the TTT paper presented at the 2003 Waste Management Conference in Tucson, AZ. This paper can be found in the library at TTT's web site: www.thortt.com.

2.0 The Drum Pyrolysis Test System

2.1. General Layout and Operation

The test system consisted of a one-drum, electrically-heated pyrolyzer and a test off-gas system consisting of a condenser, water seal pot, and exhaust blower. The condenser served to condense water and most organics to a liquid that can be disposed of. The water seal pot is used to prevent oxygen ingress into the pyrolyzer. It should be noted that an operational THOR^{SM} system utilizes a steam reforming system for off-gas treatment, and that this test system cannot be used to obtain representative emissions data.

A picture of the apparatus, without insulation, is shown in Figure 1 and a picture of the fully assembled system, ready for operation, is shown in Figure 2. The key hardware items are:

Pyrolyzer – This is the core piece of equipment, designed to heat the drums and contents to >650^{o}C. It is a 66.5" high (approx.) by 32" outside diameter vessel designed to hold a 55-gallon drum or a 55-gallon drum overpacked inside an 85-gallon drum. It is equipped with ports for off-gas removal, gas purges, pressure measurement, and temperature measurement and is fitted with resistance heaters.

Condenser – The process gases from the pyrolyzer flow to the condenser, which is designed to remove water vapor and condensable tars and oils. To accomplish this, cooling water is recirculated by a centrifugal pump through a spray nozzle in the top of the vessel to provide intimate gas-liquid contact. It is equipped with a level gage and other ports for pressure and temperature measurement. Heat rejection, as required, is accomplished by cooling water flowing through a coil in the bottom of the vessel.

Water Seal Pot – The process gases from the condenser pass through the water seal pot, which is designed to isolate the oxygen-deficient pyrolyzer system from the oxygen-rich environment. This is to prevent a safety hazard and to ensure that the transition from oxygen-deficient to oxygen-rich process off-gas is made in a safe, controlled manner.

Off-gas Blower – System and area ventilation are provided by a 1,000 cfm blower. The blower draws in room air and discharges it into the pyrolyzer skid's off-gas stack. In the stack, the ambient air is mixed with the process gases passing through the pressure control valve, forming the off-gas stream that is released to the environment.

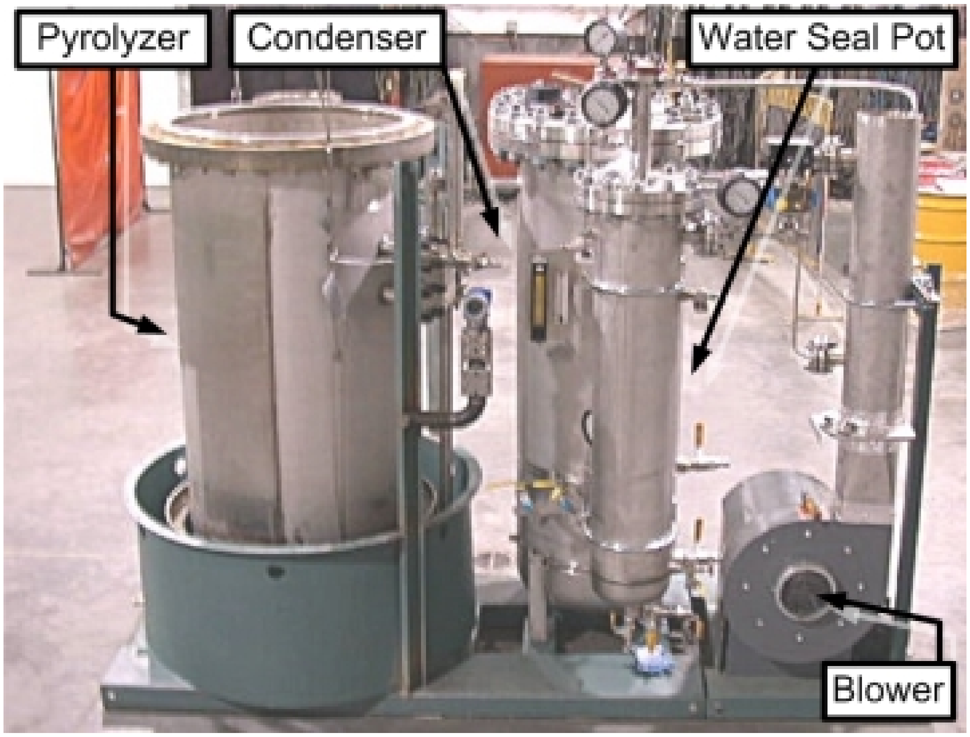

Figure 1. The THOR℠ Drum Pyrolysis Test System Without Insulation

Figure 2. The THOR℠ Drum Pyrolysis Test System Fully Assembled and Ready for Operation

The pyrolysis test system is operated via two controllers. The first is the heater control panel, pictured in Figure 3, which controls the heat input rate to the simulated waste drum in the pyrolyzer. This control panel features a breaker switch, power switches, and a digital controller, which controls the percent of maximum power output of the pyrolyzer heaters, as set by operator input. The heater controller is located approximately 10 ft from the pyrolysis skid.

Figure 3. The Heater Control Panel
Figure 4. Operator Control Station for Pyrolyzer System

The second controller is a digital control unit used to open and close the system's pressure control valve, as determined by the system operator. Variables are input to the controller to define the system pressures at which the control valve opens and closes and the interval between cycles. The controller is a small unit located at the operator control station, which is in an adjacent room approximately 15 ft from the pyrolyzer skid.

The operator control station, shown in Figure 4, is the primary location from which the system operator—also the test supervisor—monitors and controls the pyrolysis system. The unit on the left side of the desk is a total hydrocarbon (THC)/oxygen analyzer, used to monitor oxygen levels and pyrolysis gas evolution in the pyrolyzer during system operation. The blue box above the analyzer is a sample condenser, designed to protect the analyzer internals from damage by water and heavy organic tars. The pressure controller, discussed above, is the unit just to the right of the sample condenser. In addition to controlling the pressure within the system, the controller also displays the system pressure for easy monitoring by the test supervisor.

A thermocouple digital data logger is located to the right of the computer screen (out of sight). This data logger monitors the pyrolysis system temperatures and prints them out at a supervisor-determined interval, usually every 5 or 15 minutes. The test supervisor then enters the temperature data into a spreadsheet on the computer, which produces a plot of the key pyrolyzer and waste drum temperatures during system heat-up and cool-down. This allows the test supervisor to easily and accurately track system temperature profiles.

2.2. Assembly and Checkout

Between January 15 and February 2, 2004, the test system was assembled and checked out. The system checkout was performed in accordance with a formal, approved procedure, which tested all operational aspects of the system hardware and instrumentation. This included:

- Verifying system configuration
- Energizing electrical systems
- Verifying functionality of all instruments, controllers, and the data logger
- Verifying operation of heaters and other electrical systems
- Ensuring adequate supply of carbon dioxide and nitrogen industrial gases
- Setting valve positions and purge gas flows
- Checking thermocouple and pressure transducer continuity
- Adding water to the condenser and water seal pot
- Verifying condenser pump and off-gas blower operation
- Verifying proper pressure control valve operation
- Pressure testing of the entire system
- Verifying the presence of all necessary tools and supplies
- Verifying the presence of all necessary operating documents

Following a final system walk-down and safety training session, the test director—also the chief engineer—certified the system ready for operation on February 2, 2004.

3.0 Test Operations

All test operations were conducted in compliance with the Test Plan, approved by WTS, and formal, internally approved operating procedures and data sheets. Operations were carefully documented in a chronological operating log maintained by the test supervisor on each of two 12-hour shifts per day, as well as on specific data sheets filled out for each drum assembled and pyrolyzed.

The test supervisors, each experienced engineers, were assisted by one and sometimes two technicians on each shift. The technicians all had many years of experience in industrial research and development. Operations were smoothly conducted and there were no injuries or significant operational incidents.

3.1. Simulated Waste Drum Assembly

The test sequence for each drum started with the make-up of the simulated waste drum. Each of the 10 test drum assemblies started with a new 55-gallon steel drum, into which was inserted a standard 90 mil HDPE plastic liner. The simulated waste contents where then configured as specified in the Specification for Drum Contents and Data Collection, an internal document (hereafter referred to as the drum contents document) and placed into the drum. Type K thermocouples where attached to the simulated waste components, as specified in the drum contents document. From two to six thermocouples were placed on the simulated waste components in the drums, each carefully configured to allow good temperature monitoring of the intended item without interference from surrounding items (e.g., radiant heat effects). The plastic drum liner lid was then put in place, followed by the metal drum lid. The thermocouple wires were routed through ~1 inch holes punched through each lid. The closure ring was then installed and bolted in place on the 55-gallon drum.

Drums 2, 3, 4, 5, 6, and 7 were 55-gallon drums that were directly loaded into the pyrolyzer as shown in Figure 5. These drums were placed directly into the pyrolyzer. Note the thermocouple wires emerging from the top of the drum and the banding on the drum for external thermocouple attachment.

Drums 1, 8, and 9 were 55-gallon drums placed into an 85-gallon overpack, as shown in Figure 6. The thermocouple wires from the 55-gallon drum were routed through special fittings on the side of the overpack drum. A fluorescent mineral powder called Willemite was added to a specific item inside the inner drum. The intent was to use a black light to try to qualitatively determine the extent to which the powder was spread during the pyrolysis process. The Willemite was used as a surrogate for how plutonium might behave in actual TRU waste in a production pyrolysis process. The lid of the 85-gallon drum contained an integral filter designed to retain contaminants (the Willemite, in this case) inside the overpack, while allowing gases to pass freely into and out of the overpack.

Figure 5. 55-gallon Drum Ready for Pyrolysis
Figure 6. 85-gallon Overpack Containing 55-gallon Drum Ready for Pyrolysis

Preparations for pyrolysis of Drums 1, 8, and 9 were completed by the placement of thermocouples on the outside of the overpack drum, as shown in Figure 6.

3.2. Pyrolysis Operations

After each simulated waste drum was packaged and prepared for pyrolysis, it was rigged and lifted into the pyrolyzer, as shown in Figure 7.

The insulation plug was then put into place, followed by the pyrolyzer lid. The thermocouple wires were connected into the data logger system and final operational checks were completed to ensure the system was ready for heat-up.

Figure 7. Lowering 85-gallon Overpack into the Pyrolyzer

The heaters were initially set to 50% power and then increased to 90–100% power after about ten minutes. Heater output was sequentially lowered as the system heated up to the target temperature of 700°C for all drum (and waste) thermocouples. Process gas samples were periodically drawn off the bottom of the pyrolyzer and run through the THC/oxygen analyzer to check the percent total hydrocarbons and oxygen. The pyrolyzer pressure was also monitored and recorded during heat-up.

After all the drum thermocouples reached 700^{o}C, the heaters were shut off and the cool-down was started. The test supervisor recorded system and drum temperatures every 15 minutes during the entirety of the heat-up and cool-down periods.

At the end of the pyrolyzer cool-down period, the lid and insulation plug were then removed, the drum thermocouple wires were disconnected, and the drum was removed from the pyrolyzer.

3.3. Post Pyrolysis Drum Inspection

After an additional cooling period, the drum was disassembled and inspected in compliance with the drum contents document and an approved inspection procedure. The results of the inspection were recorded on the Post-Treatment Drum Observation Record. The inspection consisted of:

- Observing condition of the exterior of the drum (or overpack), including lid and closure ring
- Weighing the entire package
- If fluorescent Willemite was added to the package, inspecting all areas of the package and the interior of the pyrolyzer with a black light for the spread of Willemite
- If overpacked:
  - Removing the overpack lid and inspecting the filter
  - Removing the 55-gallon drum from overpack
  - Observing the condition of exterior of the 55-gallon drum
  - Weighing the 55-gallon drum and empty overpack
- Removing 55-gallon drum lid and observing contents
  - Observing the condition of drum lid gasket
- Removing and inspecting the 55-gallon drum contents:
  - Checking for free liquids
  - Inspecting aerosol cans and checking for indications of breach
  - Inspecting exteriors of 1-gallon and 5-gallon paint cans and checking for indications of breach
  - Performing bubble leak tests on 1-gallon paint cans, if necessary to determine breach
  - Inspecting interiors of 1-gallon and 5-gallon paint cans
  - Observing condition of 5-gallon paint can gaskets
- Inspecting the balance of the contents of the drum—e.g., insulated wire, craft paper, absorbent wipes, gypsum sheet rock, concrete blocks, scrap metal, plastic hose, free water, dried strippable coating paint, mop heads, cellulose filters, and paint brushes.

In addition to making a written record of inspection result, digital pictures were taken of most of the items inspected. Videos were taken of representative inspections.

4.0 Test Results

The demonstration testing was completely successful, as all test objectives were met:

- All prohibited items were removed from drums:
  - All free liquids were removed
  - All sealed containers were breached
  - All aerosol cans were breached

- The THOR^{SM} pyrolysis process yielded mass reduction for all drums tested. Each assembled 55-gallon drum was weighed before and after testing, and the weight reduction for each drum is shown in the table below. The weight reductions are proportional to the mass of water and organics present in each drum. If the 55-gallon drum had been compacted post-pyrolysis, the estimated volume reduction attainable is also shown in the table below. It should be noted that Drums 6, 8, 9, and 10 have a lower volume reduction because these drums contained non-compactable scrap metal and concrete.

Table 1—Weight and Volume Reduction

Drum No.	Weight Reduction (Drum Weight Before Testing Less Drum Weight After Testing)	Estimated Drum Volume Reduction if Drum Were to Be Compacted
1	35.1 %	90 %
2	17.3 %	80 %
3	17.3 %	80 %
4	20.4 %	80 %
5	20.3 %	90 %
6	8.6 %	40 %
7	23.5 %	80 %
8	22.4 %	60 %
9	20.9 %	50%
10	10.3 %	40 %

- Based on visual inspections, the organic volume of drum content was reduced by 70-90%, depending on the organic content. For example, if the original volume of waste were 10 cubic feet, and treatment produced a 90% reduction, then the post-treatment volume would only be 1 cubic foot.

- The THOR^{SM} 85-gallon overpack with its integral filter provided containment and criticality control, as airborne particles were retained in the overpack. Fluorescent Willemite added to the waste packages prior to pyrolysis was not spread outside the overpack, as indicated by black light inspection following pyrolysis.

- System pressure was carefully monitored during pyrolysis operations to observe the relative level of pyrolysis gas evolution and to detect any significant expansion surges resulting from the breach of sealed containers. No system pressure surges were observed from the breach of sealed containers, as the pressure effect of a can breach appeared to be well damped by the dynamics of the system. No expulsion of solids from a drum or bulging of a drum was apparent from post-treatment inspections.

- The thermal performance of the test pyrolyzer is provided in a separate deliverable entitled Thermal Performance Report. This deliverable provides heat-up and residence times for all drums tested. It also provides an evaluation of the temperature and off-gas data that provides evidence that organics are destroyed and have been volatized. Finally, this document provides a thermal model that predicts residence and cooldown time for drums of varying weight and composition.

4.1. Test Results for Drum #1

Drum #1 consisted of a 55-gallon drum with a standard 90 mil HDPE drum liner overpacked inside an 85-gallon drum, into which was placed:

- 2 gallons of water
- 1 tsp fluorescent Willemite powder

Thermocouples were placed:

- At the bottom of the 55-gallon drum interior
- On the drum exterior approximately 10 inches down from the top.
- On the outside of the overpack as shown in Figure 8.

The 55-gallon drum was placed into the 85-gallon drum overpack. The final package, ready for pyrolysis, is shown in Figure 8. The drum was then placed into the pyrolyzer and the heat-up was begun.

The heat-up and cool-down of Drum #1 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.

Following cool-down, the package was removed from the pyrolyzer and was inspected. The black light inspection of the inside of the pyrolyzer and the outside of the overpack indicated no Willemite.

The general appearance of the overpack following pyrolysis is shown in Figure 9. Aside from the light gray color, the overpack was in very good condition, with no damage observed. The filter on the overpack lid was designed to contain non-volatile drum contents during treatment. The total weight of the loaded package decreased from 175.2 lbs to 142.1 lbs, a loss of 33.1 lb or 18.9% as a result of treatment.



Figure 8. Drum #1 Ready for Pyrolysis
Figure 9. Drum #1 Following Pyrolysis
Figure 10. Filter from Drum #1 Following Pyrolysis

As shown in Figure 10, the filter was not breached. The filter appeared to efficiently retain the pyrolyzed residues inside the drums.

The inner 55-gallon drum was removed from the overpack and weighed. The total weight of the loaded 55-gallon drum decreased from 95.4 lbs to 61.9 lbs, a loss of 33.5 lb or 35.1% as a result of treatment.

If the drums and its contents (none in this case) were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 90 % would be achieved.

The 55-gallon drum lid was then removed, revealing an empty 55-gallon drum, light gray in color, with some paint flakes. The gasket seal on the drum lid had volatized leaving only a friable carbon residue. A black light examination revealed no fluorescent material. It was found that the initial available black light was not sufficiently powerful to make the Willemite fluoresce. For later drums, a different, more powerful, black light was used.

There was an ~2-inch high black “bathtub ring” at the bottom of the 55-gallon drum. This was a film of carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner.

4.2. Test Results for Drum #2

Drum #2 consisted of a 55-gallon drum (no overpack) with a standard 90 mil HDPE drum liner, into which was placed:

- One sealed 1-gallon paint can containing ~2 cups of water
- One sealed 1-gallon paint can containing ~1 cup of paint
- One sealed 1-gallon paint can containing triple-bagged scrap metal
- One sealed 1-gallon paint can containing scrap metal only

Thermocouples were placed:

- On the side of each of the four one-gallon paint cans (see Figure 11).
- Two on the side of the 55-gallon drum, one high and one low.

The four one-gallon cans were then placed into the 55-gallon drum, as shown in Figure 12. The drum, with thermocouple wires and liner lid in place is shown in Figure 13. The metal drum lid with elastomeric gasket was then put in place and secured with a seal ring. The drum was then placed into the pyrolyzer and the heat-up was begun.

The heat-up and cool-down of Drum #2 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.

Following cool-down, the drum was removed from the pyrolyzer and was inspected. The general appearance of the drum following pyrolysis is shown in Figure 14, along with the drum-lifting tool. Aside from the gray color and the presence of a light residue of flaking paint, the drum was in good condition, with no damage apparent. The drum closure ring was loose because the lid gasket had been volatilized. The total weight of the loaded drum decreased from 107.0 lbs to 88.5 lbs, a loss of 18.5 lbs or 17.4% as a result of treatment.


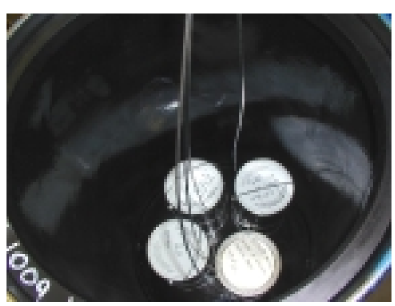


Figure 11. Four One-Gallon Paint Cans for Drum #2 Prior to Pyrolysis, Showing Thermocouple Attachment
Figure 12. Four One-Gallon Paint Cans in Drum #2 Prior to Pyrolysis
Figure 13. Drum #2 Ready for Final Closure with Liner Lid and Thermocouple Wires in Place

If the 55-gallon drum and its contents were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 85% would be achieved.

Figure 14. Drum #2 Following Pyrolysis
Figure 15. The Interior of Drum #2 Following Pyrolysis

The lid was then removed from the 55-gallon drum, revealing the contents as shown in Figure 15. Upon removal from the drum, the contents appeared as shown in Figure 16. All of the cans in the drum were breached.

The lid of the can that had contained ~2 cups of water had popped off and flipped upside down and was resting back on the top of the can. The can contained only some very light paint flake residues. The sides of the can had slightly buckled inward.

The lid of the can that had contained ~1 cup of paint had popped off and was lying upside down on the bottom of the drum. The can contained pyrolyzed paint flake residues that looked much like dried cake on a dried lakebed. The sides of the can had slightly buckled inward.

Figure 16. The Contents of Drum #2 Following Pyrolysis
Figure 17. Paint Can from Drum #2 After Pyrolysis. Arrows indicate Leak Points

The can that had contained the scrap metal with the plastic bags and tape had sustained significant deformation of the sides and there was an ~1/8-inch gap between the lid and the top of the can at one point. The lid itself was not deformed.

The can that had contained the scrap metal without the plastic bags and tape had sustained heavy buckling, but there was no visually apparent gap or leak point at the lid. When the can was submerged in 3–4 inches of water, the can leaked in three places (see Figure 17, leak points are noted with white arrows). The lid seal leaked in two places and a crease in the side had an even larger leak.

There was an ~2-inch high black “bathtub ring” at the inside bottom of the 55-gallon drum that was also apparent on the 1-gallon cans shown in Figure 16. This thin film was formed of carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner.

4.3. Test Results for Drum #3

Drum #3 consisted of a 55-gallon drum (no overpack) with a standard 90 mil HDPE drum liner, into which was placed:

- One 5-gallon paint can containing scrap metal that had been triple bagged (inside the can) with plastic bags and masking tape
- Five empty WD-40 aerosol cans.
- Five empty paint aerosol cans.

Thermocouples were placed:

- Two on the sides of two of the WD-40 aerosol cans.
- Two on the sides of two of the paint aerosol cans.
- One on the side of the 5-gallon paint can.
- One on the outside of the 55-gallon drum.

The contents of drum were arranged as shown in Figure 18.



Figure 18. The Contents of Drum #3 Prior to Pyrolysis
Figure 19. Drum #3 Ready for Pyrolysis
Figure 20. Drum #3 Following Pyrolysis

The 55-gallon drum was then assembled and lid sealed. The final package, ready for pyrolysis, is shown in Figure 19. The drum was then placed into the pyrolyzer and the heat-up was begun.

The heat-up and cool-down of Drum #3 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.

Following cool-down, the drum was removed from the pyrolyzer and was inspected. The general appearance of the drum following pyrolysis is shown in Figure 20. Aside from the gray color and the presence of a light residue of flaking paint, the drum was in good condition, with no damage apparent. The seal on the drum lid had been lost, as the lid gasket was volatilized with only a friable carbon residue remaining. The total weight of the drum decreased from 100.0 lbs to 82.7 lbs, a loss of 17.3 lbs or 17.3% as a result of treatment.

If the 55-gallon drum and its contents were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 80% would be achieved.

The lid was then removed from the 55-gallon drum and the contents were inspected and then removed, as shown in Figure 21. All of the cans in the drum were breached.

The plastic stems in all of the aerosol cans were gone and all of the top can seals turned freely. A rod dropped into each of the stem holes fell immediately to the bottom. There were no bulges or dents in the aerosol cans.

The 5-gallon paint can that had contained scrap metal and plastic bags had a loose lid, with its gasket pyrolyzed with only a very friable residue remaining in a few locations in the lid groove. There was a light, black carbon residue inside the can, along with a few highly friable sleeves, the remains of the masking tape that had been used to seal the plastic bags. There was no bulging or deformation of the can body.

There was an ~2-inch high black "bathtub ring" at the bottom of the 55-gallon drum, as shown in Figure 22. This was a thin film of carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner. This ring was also apparent on the aerosol cans shown in Figure 21. There were also black streaks apparent down the inside of the drum indicating the flow of the melting drum liner.

Figure 21. The Contents of Drum #3 Following Pyrolysis
Figure 22. The Bottom of Drum #3 Following Pyrolysis with cans removed

4.4. Test Results for Drum #4

Drum #4 consisted of a 55-gallon drum (no overpack) with a standard 90 mil HDPE drum liner, into which was placed:

- A 1-gallon paint can containing scrap metal that has been triple bagged (inside the can) with plastic bags and masking tape. The 1-gallon paint can was then triple bagged with plastic bags and masking tape (outside the can).
- One WD-40 aerosol can ~25% full.
- A 1-gallon paint can, ~75% full of anion exchange resin (Resin Tech SBG-RTI-10625), and covered with filter material (no metal lid).
- Two sets of heavy latex shoe covers.
- One set of lighter latex shoe covers.

Thermocouples were placed:

- One on the inside of the can with the anion exchange resin.
- One on the side of the 1-gallon paint can containing scrap metal.
- One on the outside of the outermost plastic bag containing the 1-gallon scrap metal can.
- One in the middle of the heavy shoe covers.
- Two on the outside of the 55-gallon drum, one near the top and one at the bottom.

The contents of drum were arranged as shown in Figure 23.

Figure 23. The Contents of Drum #4 Prior to Pyrolysis
Figure 24. Drum #4 Ready for Pyrolysis

The 55-gallon drum was then assembled. The final package, ready for pyrolysis, is shown in Figure 24. The drum was then placed into the pyrolyzer and the heat-up was begun.

The heat-up and cool-down of Drum #4 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.

Following cool-down, the drum was removed from the pyrolyzer and was inspected. The general appearance of the drum following pyrolysis is shown in Figure 25. Aside from the gray color and the presence of a light residue of flaking paint on the lid, the drum was in good condition, with no damage apparent. The seal on the drum lid had been lost, as the lid gasket was pyrolyzed with only a carbon residue remaining in the lid groove. The total weight of the drum decreased from 108.7 lbs to 86.6 lbs, a loss of 22.1 lbs or 20.3% as a result of treatment.

If the 55-gallon drum and its contents were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 85% would be achieved.


Figure 25. Drum #4 Following Pyrolysis
Figure 26. The Contents of Drum #4 Following Pyrolysis
Figure 27. Aerosol Can from Drum #4 Following Pyrolysis

The lid was then removed from the 55-gallon drum and the contents were inspected and then removed, as shown in Figure 26. All of the cans in the drum were breached.

The plastic stem in the aerosol can was gone and the top can seal turned freely. A rod dropped into the stem hole fell immediately to the bottom. There were no bulges or dents in the aerosol can. There was a dark stain on about half of the aerosol can from the melting, pooling, and subsequent volatilization of the drum liner (see Figure 27).

The 1-gallon can that had contained the anion exchange resin is pictured in Figure 28. The bottom of the can was bulged outward ~1/2 inch. The filter material covering the can was stiff and bowed upward and had an ~1/8 inch black coating on the inside surface. The resin inside the can was reduced to ~1/6th its original volume and was friable.

Figure 28. 1-Gallon Can of Anion Exchange Resin from Drum #4 Following Pyrolysis
Figure 29. 1-Gallon Can of Scrap Metal from Drum #4 Following Pyrolysis
Figure 30. The Bottom of Drum #4 Following Pyrolysis

The 1-gallon paint can containing scrap metal and plastic is pictured in Figure 29. The can was severely buckled and the lid was lifted slightly in two areas. The can exhibited significant leakage at the lid when submerged in water.

The heavy and lighter shoe covers were reduced to a small pile of crunchy foam-like curls in the bottom of the drum.

There was an ~2-inch high black “bathtub ring” at the bottom of the 55-gallon drum, as shown in Figure 30. This was a film of carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner. There were also black streaks apparent down the inside of the drum indicating the flow of the melting drum liner.

4.5. Test Results for Drum #5

Drum #5 consisted of a 55-gallon drum (no overpack) with a standard 90 mil HDPE drum liner (no liner lid installed), into was placed:

- Fifteen feet of plastic hose, triple bagged with plastic bags and masking tape.

Two thermocouples were placed:

- On the outside of the 55-gallon drum, one near the top and one near the bottom.
- Two more thermocouples were each inserted approximately 7 inches into each open end of the plastic tubing.

Assembly of the 55-gallon drum package was then completed. The final package, ready for pyrolysis, is shown in Figure 31. The drum was then placed into the pyrolyzer and the heat-up was begun.

Figure 31. Drum #5 Ready for Pyrolysis
Figure 32. Drum #5 Following Pyrolysis

The heat-up and cool-down of Drum #5 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.

Following cool-down, the drum was removed from the pyrolyzer and was inspected. The general appearance of the drum following pyrolysis is shown in Figure 32. Aside from the light gray to black color, the drum was in very good condition, with no damage observed. The seal on the drum lid had been lost, as the lid gasket was pyrolyzed leaving only a friable residue in the lid groove. The total weight of the drum decreased from 78.7 lbs to 62.7 lbs, a loss of 16.0 lbs or 20.3% as a result of treatment.

If the 55-gallon drum and its contents were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 90% would be achieved.

All that remained in the drum from the plastic tubing and the plastic bags and tape were the remains of the tape sleeves, much reduced in volume and highly friable. There was an ~2-inch high black "bathtub ring" at the bottom of the 55-gallon drum, as shown in Figure 33. This was a film of carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner. There were also black streaks apparent down the inside of the drum indicating the flow of the melting drum liner.

Figure 33. Bottom of Drum #5 Following Pyrolysis

4.6. Test Results for Drum #6

Drum #6 consisted of a 55-gallon drum (no overpack) with a standard 90 mil HDPE drum liner, into which was placed:

- One 5-gallon paint can containing ~1 cup of paint. The can was then triple bagged with plastic bags and masking tape.
- Thirteen concrete cinder blocks to bring weight of drum up to ~350 lbs (actual weight was 357 lbs)

Thermocouples were placed:

- Two on the side of the 5-gallon can, one near the top and one near the bottom.
- Three in the formed holes in the 4" concrete blocks—one ~5 inches off the bottom of the drum and ~4 inches from the wall, the second ~10 inches from the top of the drum near the centerline, and the third near the center of the drum, both axially and radially.
- One on the outside of the 55-gallon drum ~10 inches down from the top.

The contents of the drum were arranged as shown in Figure 34 and Figure 35. In the figures the plastic bags are pulled back to reveal the positioning of some of the concrete blocks. The bags were sealed prior to completing drum assembly and closure.

Figure 34. Contents of Lower Half of Drum #6 Prior to Pyrolysis.
Figure 35. Contents of Upper Half of Drum #6 Prior to Pyrolysis.

The 55-gallon drum was then closed, the drum was placed into the pyrolyzer, and the heat-up was begun.

The heat-up and cool-down of Drum #6 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.

Following cool-down, the drum was removed from the pyrolyzer and was inspected. The general appearance of the drum following pyrolysis is shown in Figure 36. Aside from the gray color and the presence of a large area of light residue of flaking paint, the drum was in good condition, with no damage apparent. The seal on the drum lid had been lost, as the lid gasket was pyrolyzed leaving only a friable residue in the lid groove. The total weight of the drum decreased from 357.0 lbs to 326.2 lbs, a loss of 30.8 lbs or 8.6% as a result of treatment.

If the 55-gallon drum and its contents were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 40% would be achieved (limited by the presence of many relatively non-compactable concrete blocks).

  

Figure 36. Drum #6 Following Pyrolysis
Figure 37. Contents of Upper Half of Drum #6 Following Pyrolysis
Figure 38. The Contents of Lower Half of Drum #6 Following Pyrolysis

The lid was then removed from the 55-gallon drum, revealing the contents as shown in Figure 37 and Figure 38. The contents were removed and inspected.

The 5-gallon paint can that had contained ~1cup of paint was coated with a cracked black crust ~1/16 inch thick that required mechanical action to dislodge (see Figure 39). This coating was probably the result of the melting plastic in the drum running down onto the can and then pyrolyzing. The can lid was loose, its gasket having been volatilized away. There was ~1/8 inch thick cracked carbonized paint residue inside the can, looked much like a dried lakebed. There was no bulging or deformation of the can body.

Figure 39. 5-Gallon Can from Drum #6 Following Pyrolysis

The concrete blocks that had been placed into the drum were fully intact, but had been stained by the melting/pyrolyzing plastic liner and bags (see Figure 40).


Figure 40. Concrete Blocks from Drum #6 Following Pyrolysis
Figure 41. The Bottom of Drum #6 Following Pyrolysis with 5-gallon can and concrete blocks removed

There was an ~2-inch high black "bathtub ring" at the bottom of the 55-gallon drum, as shown in Figure 41. This was a thin film of carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner. There were also black streaks apparent down the inside of the drum indicating the flow of the melting drum liner. The outline of where the 5-gallon can rested on the bottom of the drum is evident in the figure.

4.7. Test Results for Drum #7

Drum #7 consisted of a 55-gallon drum (no overpack) with a standard 90 mil HDPE drum liner, into which was placed:

- Forty absorbent wipes moistened with water and approximately 1 ft^3 of craft paper, combined into a single package and then triple bagged with plastic bags and masking tape.
- A sealed 1-gallon can of scrap metal, with the scrap metal triple bagged with plastic bags and masking tape inside the can.
- A sealed 5-gallon paint can, containing approximately 2 cups of paint, triple bagged with plastic bags and masking tape.
- An empty WD-40 aerosol can, triple bagged with plastic bags and masking tape.
- Two cellulose mop heads, saturated with WD-40, triple bagged with plastic bags and masking tape.

One thermocouples was placed in each of the following locations:

- On the side of the 5-gallon paint can.
- On the side of the WD-40 can.
- On the side of the 1-gallon paint can.
- Clamped to the absorbent wipes.
- Clamped around the middle of the mop heads.
- On the exterior side of the 55-gallon drum, at the bottom.

The 55-gallon drum was then assembled. The final package, ready for pyrolysis, is shown in Figure 42. The drum was then placed into the pyrolyzer and the heat-up was begun.


Figure 42. Drum #7 Ready for Pyrolysis
Figure 43. Drum #7 Following Pyrolysis

The heat-up and cool-down of Drum #7 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.

Following cool-down, the drum was removed from the pyrolyzer and the package was inspected. The general appearance of the 55-gallon drum following pyrolysis is shown in Figure 43. Aside from the light gray color and the presence of a light residue of flaking paint, the drum was in good condition, with no damage apparent. The seal on the drum lid had been lost, as the lid gasket was pyrolyzed with only a friable residue remaining in the lid groove. The total weight of the loaded drum decreased from 113.5 lbs to 86.8 lbs, a loss of 26.7 lb or 23.5% as a result of treatment.

If the 55-gallon drum and its contents were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 80% would be achieved.

The lid was then removed from the 55-gallon drum, revealing the contents as shown in Figure 44. All of the cans in the drum were breached.


Figure 44. The Interior of Drum #7 Following Pyrolysis
Figure 45. Aerosol Can from Drum #7 Following Pyrolysis
Figure 46. 5-Gallon Paint Can from Drum #7 Following Pyrolysis

The plastic stem in the aerosol can was gone and the top can seal turned freely. A rod dropped into the stem hole fell immediately to the bottom. There were no bulges or dents in the can. There was a dark stain on the aerosol can, probably from the melting and subsequent pyrolysis of the plastic bags in which it had been wrapped (see Figure 45). Note the thermocouple still attached.

The 5-gallon paint can that had contained the paint was not deformed, as can be seen in Figure 46. The can lid was loose, its gasket having pyrolyzed with only a small amount of friable residue remaining in the lid groove. The paint that had been added to the can had been pyrolyzed and formed a thin cracked crust, much like a dried lakebed.

The 1-gallon paint can with the scrap metal and plastic had its lid bent upward slightly in one area, as shown in Figure 47. The can's side was also dented and upon submergence in water, air bubbled profusely from the can lid, as seen in Figure 48, clearly indicating the can was breached.

Figure 47. 1-Gallon Paint Can from Drum #7 Following Pyrolysis
Figure 48. 1-Gallon Can from Drum #7 During Post-Pyrolysis Leak Testing

The absorbent wipes and the craft paper were both greatly reduced in mass and volume and were very friable, much like newspaper ash. The mop heads had shrunk in volume ~50% and were greatly reduced in mass. The strings could be easily broken apart by hand, but were not as friable as the paper following pyrolysis. Figure 49 shows the remains of these items in the bottom of the drum following pyrolysis. Figure 50 shows a mop head after pyrolysis, as compared to an untreated mop head.

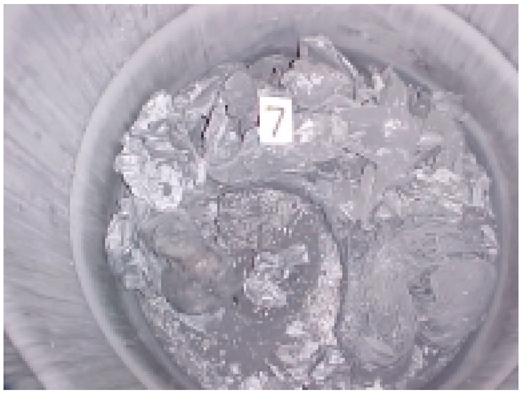

Figure 49. The Remains of the Paper and Mop Heads Pyrolyzed in Drum #7
Figure 50. A Pyrolyzed Mop Head from Drum #7 Compared to an Untreated Mop Head

There was an ~2-inch high black "bathtub ring" at the bottom of the 55-gallon drum, as can be seen in Figure 49. This was a film of carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner. There were also black streaks apparent down the inside of the drum indicating the flow of the melting drum liner.

4.8. Test Results for Drum #8

Drum #8 consisted of an overpacked 55-gallon drum containing a standard 90 mil HDPE drum liner, into which was placed:

- Approximately 1 gallon of free water.
- One sealed 5-gallon metal can, containing approximately 1 gallon of scrap metal, triple bagged with plastic bags and masking tape. The bagged scrap metal was then placed inside a 5-gallon metal can that was then sealed. 1 teaspoon of fluorescent Willemite powder was placed between the second and third bags.
- One sealed 1-gallon metal paint can, containing approximately 1 cup of water poured into the inner plastic bag, triple bagged with plastic bags and masking tape. The bagged water was then placed into the 1-gallon can and sealed.
- One empty WD-40 aerosol can, triple bagged with plastic bags and masking tape.
- Forty absorbent wipes moistened with water and approximately 1 ft^3 of craft paper, combined into a single package and then triple bagged with plastic bags and masking tape.
- 100 ft of 12-gage insulated electrical wiring, triple bagged with plastic bags and masking tape.
- Five 1-foot squares of ½” gypsum sheet rock, triple bagged with plastic bags and masking tape.
- Two concrete blocks, each weighing about 21 lbs, triple bagged with plastic bags and masking tape.

Thermocouples were placed:

- On the 1-gallon paint can and to one of the concrete blocks.
- To the outside of the overpack as shown in Figure 51.

The 55-gallon drum was then assembled into the overpack package. The final package, ready for pyrolysis, is shown in Figure 51. The package was then placed into the pyrolyzer and the heat-up was begun.

The heat-up and cool-down of Drum #8 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.



Figure 51. Drum #8 Ready for Pyrolysis
Figure 52. Drum #8 Following Pyrolysis
Figure 53. Filter from Drum #8 Following Pyrolysis

Following cool-down, the drum was removed from the pyrolyzer and the package was inspected. The black light inspection of the inside of the pyrolyzer and the outside of the overpack indicated no Willemite.

The general appearance of the overpack following pyrolysis is shown in Figure 52. Aside from the light gray color from pyrolyzed paint, the overpack was in very good condition, with no damage observed. The total weight of the package decreased from 240.0 lbs to 203.2 lbs, a loss of 36.1 lbs or 15.3% as a result of treatment.

As shown in Figure 53, the filter was not breached, but was coated with carbon residues on the undersides. This is as expected, given the flow of pyrolysis gases out of the drum.

The inner 55-gallon drum was removed from the overpack, inspected, and weighed. The lid was then removed, revealing the contents as shown in Figure 54. All of the cans in the drum were breached. The total weight of the drum decreased from 161.1 lbs to 125.0 lbs, a loss of 36.1 lbs or 22.4% as a result of treatment.

If the 55-gallon drum and its contents were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 60% would be achieved (limited by the concrete blocks in the drum).

The plastic stem in the aerosol can was gone and the top can seal turned freely (see Figure 55). A rod dropped into the stem hole of the aerosol can fell immediately to the bottom.

The 1-gallon paint can that had contained 1 cup of water had its lid bent upward around an ~120^{o} arc and was clearly open, as shown in Figure 56. There was no bulging or deformation of the can body. When submerged under an inch of water, a steady stream of bubbles issued from the 1-gallon can lid.

Figure 54. The Interior of Drum #8 Following Pyrolysis
Figure 55. Aerosol Can and Insulated Wire Following Pyrolysis in Drum #8

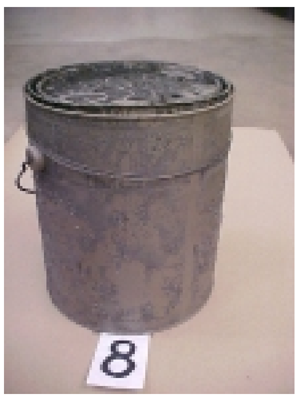

Figure 56. 1-Gallon Can from Drum #8 Following Pyrolysis
Figure 57. Interior of 5-Gallon Can from Drum # 8 Following Pyrolysis

The 5-gallon paint can that had contained scrap metal and plastic bags had a loose lid in the vertical direction, since its gasket was mostly gone and what remained was friable. There was no bulging or deformation of the can body. The inside of the can contained a light carbon residue from pyrolysis of the can coating and the plastic bags (see Figure 57).

The balance of drum contents is shown in Figure 54 and Figure 57. The paper coating on the gypsum sheet rock was gone and the gypsum itself was friable, and partially broken. The craft paper was greatly reduced in mass and volume and was very light and friable, like newspaper ash. The absorbent wipes were much the same. The 12-gage insulated wire was as shown in Figure 55. The insulation was reduced to a dark crusty residue.

There was an ~2-inch high black “bathtub ring” at the bottom of the 55-gallon drum. This was the residual film of carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner. The concrete blocks and the 5-gallon can that were resting on the bottom of the drum also show this residue ring.

4.9. Test Results for Drum #9

Drum #9 consisted of an overpacked 55-gallon drum containing a standard 90 mil HDPE drum liner, into which was placed:

- One 5-gallon metal can, containing approximately 1 gallon of scrap metal, triple bagged with plastic bags and masking tape. The triple bagged scrap metal was placed inside a 5-gallon metal can and the can lid was then sealed. 1 teaspoon of fluorescent Willemite powder was placed between the second and third bags.
- One sealed 1-gallon metal paint can, containing approximately 2 cup of paint inside the inner bag. The bagged paint was triple bagged with plastic bags and masking tape.
- One empty WD-40 aerosol can, triple bagged with plastic bags and masking tape.
- Fifteen feet of plastic hose, triple bagged with plastic bags and masking tape.
- Dried Bartlett Stripcoat TLC (strippable coating) that had been coated on a flat metal surface, dried, and then stripped off to form ~1 ft^3 of material when loosely bunched together. This, along with 18 cellulose filter cartridges were combined into a single bundle that was triple bagged with plastic bags and masking tape.
- Seven concrete blocks, each weighing about 21 lbs, triple bagged with plastic bags and masking tape, to bring the weight up to approximately 250 lbs.

Thermocouples were placed:

- On the 1-gallon paint can and to one of the concrete blocks.
- On the outside of the overpack as shown in Figure 58.

The 55-gallon drum was then assembled into the overpack package. The final package, ready for pyrolysis, is shown in Figure 58. The drums were then placed into the pyrolyzer and the heat-up was begun.

Figure 58. Drum #9 Ready for Pyrolysis
Figure 59. Drum #9 Following Pyrolysis

The heat-up and cool-down of Drum #9 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.

Following cool-down, the drum was removed from the pyrolyzer and the package was inspected. The black light inspection of the inside of the pyrolyzer and the outside of the overpack indicated the possibility of 2 tiny glow spots inside the pyrolyzer and ~10 glow spots on top of the overpack lid. It is uncertain that these were actually Willemite, as they were so dull in fluorescence. It is possible that the glow spots were Willemite dulled with carbon residue, and it is also possible that the glow spots were insulation fibers.

The general appearance of the overpack following pyrolysis is shown in Figure 59. Aside from the light gray color from pyrolyzed paint, the overpack was in good condition, with no damage observed. The total weight of the package decreased from 335.8 lbs to 282.2 lbs, a loss of 53.6 lbs or 16.0% as a result of treatment.

The filter was not breached. The filter was coated with a carbon residue, as expected from the flow of pyrolysis gas out of the drum.

The 55-gallon drum was in good condition, with a nearly clean lid and a very light flaking paint residue on the sides (see Figure 60). The lid was then removed, revealing the contents as shown in Figure 61. All of the cans in the 55-gallon drum were breached. The 55-gallon drum was removed from the overpack and weighed. The total weight of the drum decreased from 257.0 lbs to 203.2 lbs, a loss of 53.8 lbs or 20.9% as a result of pyrolysis.

If the 55-gallon drum and its contents were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 50% would be achieved (limited by presence of relatively non-compactable concrete blocks).



Figure 60. Drum #9 Inner 55-Gallon Drum Following Pyrolysis
Figure 61. The Interior of 55-gallon Drum #9 Following Pyrolysis
Figure 62. Aerosol Can Following Pyrolysis in Drum #9

The plastic stem in the aerosol can was gone and the top can seal turned freely (see Figure 62). A rod dropped into the stem hole of the aerosol can fell immediately to the bottom. There were no bulges or dents in the aerosol can.

The 1-gallon paint can that had contained 2 cups of paint was badly deformed, as shown in Figure 63. The can lid was clearly not sealed upon observation. When submerged under 3-4 inches of water, a steady stream of bubbles issued from the can lid and from a breach in its side (at the point of sharp buckling in side of can). The interior of the 1-gallon can contained only a light, cracked paint residue.

The 5-gallon paint can that had contained scrap metal and plastic bags had a loose lid, with its gasket mostly volatilize away. There was no bulging or deformation of the can body (see Figure 64).

Figure 63. 1-Gallon Can from Drum #9 Following Pyrolysis
Figure 64. Exterior of 5-Gallon Can from Drum #9 Following Pyrolysis
Figure 65. A Cellulose Filter of the Type Loaded into Drum #9, Along with the Remains of Three Filters Following Pyrolysis

No trace remained inside the 55-gallon drum of the plastic tubing or the Stripcoat paint. The 18 cellulose cartridges were reduced to a highly friable carbon objects, only a small fraction of their former mass, as can be seen in Figure 65. The residues of the filter elements could very easily be crushed by hand with the crushed remains being similar to heavy newspaper ash.

There was an ~2-inch high black "bathtub ring" at the bottom interior of the 55-gallon drum. This was the carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner. The concrete blocks and the 5-gallon can that were resting on the bottom of the drum also show this residue ring.

4.10. Test Results for Drum #10

Drum #10 consisted of a 55-gallon drum (no overpack) with a standard 90 mil HDPE drum liner, into which was placed:

- One 5-gallon metal can, containing approximately 1 gallon of scrap metal, triple bagged with plastic bags and masking tape. The triple bagged scrap metal was then placed inside a 5-gallon metal can and the can lid was sealed.
- One sealed 5-gallon metal paint can, containing approximately 2 cup of paint in the innermost of three plastic bags that were each sealed with masking tape. The triple bagged paint was placed inside the 5-gal can and the can lid was sealed.
- One empty WD-40 aerosol can, triple bagged with plastic bags and masking tape.
- Two cellulose mop heads, saturated with WD-40, triple bagged with plastic bags and masking tape.
- Three 4-inch paintbrushes with plastic handles, triple bagged with plastic bags and masking tape.
- Nine concrete blocks, each weighing about 21 lbs, triple bagged with plastic bags and masking tape, to bring the weight up to approximately 305 lbs. (There was not sufficient room in the drum to add enough concrete blocks to bring the drum weight up to 350 lbs, as desired.)

Thermocouples were placed:

- On the side of the 5-gallon paint can containing the scrap metal.
- On the side of the WD-40 can.
- Three on concrete blocks. One was located near the center of the drum, one near the drum wall, and the third about halfway between the other two.
- On the exterior side of the 55-gallon drum, near the top.

The 55-gallon drum was then assembled. The final package, ready for pyrolysis, is shown in Figure 66. The drum was then placed into the pyrolyzer and the heat-up was begun.

The heat-up and cool-down of Drum #10 proceeded normally, with no unusual or off-normal observations. System temperatures, pressures, and THC readings were observed and recorded during the heat-up and cool-down phases. Testing was terminated after all thermocouples reached 700˚C.


Figure 66. Drum #10 Ready for Pyrolysis
Figure 67. Drum #10 Following Pyrolysis

Following cool-down, the drum was removed from the pyrolyzer and the package was inspected. The general appearance of the 55-gallon drum following pyrolysis is shown in Figure 67. Aside from the gray color and the presence of a light residue of flaking paint, the drum was in good condition, with no damage apparent. The total weight of the drum decreased from 305.0 lbs to 273.7 lbs, a loss of 31.3 lbs or 10.3% as a result of treatment. This small weight reduction was not surprising, given the small percentage of organic constituents in the initial package.

If the 55-gallon drum and its contents were compacted in a low speed compactor following pyrolysis, it is estimated that a total volume reduction of 40% would be achieved (limited by the presence of several relatively non-compactable concrete blocks).

The lid was then removed from the 55-gallon drum, revealing the contents as shown in Figure 68. Upon removal from the drum, the contents appeared as shown in Figure 69. All of the cans in the drum were breached.

Figure 68. The Interior of Drum #10 Following Pyrolysis
Figure 69. The Contents of Drum#10 Following Pyrolysis

The plastic stem in the aerosol can was gone and the top can seal turned freely. A rod dropped into the stem hole fell immediately to the bottom. There were no bulges or dents in the aerosol can.

The 5-gallon paint can that had contained the scrap metal and plastic bags was badly deformed, as can be seen in Figure 69. This was from the weight of the concrete blocks on top of the can, combined with the elevated pyrolysis temperatures. The can lid was loose, its gasket having mostly volatilized. The residual gasket comprised friable carbon residues.

The 5-gallon paint can that had contained the two cups of paint also had a loose lid, with its gasket mostly volatilize away and a friable residue remaining in the lid groove in a few places. There was no bulging or deformation of the can body. The interior of the 5-gallon can contained only a light, cracked paint residue.

The three paintbrushes were completely gone except for the metal parts between the handle and bristles. The mop heads were shrunk in size and greatly reduced in mass. The strings could be easily broken apart by hand, but were not as friable as the paper and cellulose filters had been after pyrolysis.

There was an ~2-inch high black “bathtub ring” at the bottom of the 55-gallon drum. This was a film of carbon-rich char residue from the melting, pooling, and ultimate volatilization of the drum liner. The concrete blocks and the 5-gallon can that were resting on the bottom of the drum also show this residue ring.