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Determination of Fire Environment in Stacked Cargo Containers with Radioactive Materials Packages

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Prepared by
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Determination of Fire Enviroment in Stacked Cargo Containers with Radioactive Materials Packages

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Abstract

Results from a fire test with a three-by-three stack of standard 6 m long International Standards Organization shipping containers containing combustible fuels and empty radioactive materials packages are reported and discussed. The stack is intended to simulate fire conditions that could occur during on-deck stowage on container cargo ships. The fire is initated by locating the container stack adjacent to a 9.8 x 6 m pool fire. Temperatures of both cargoes (empty and simulated radioactive materials packages) and containers are recorded and reported. Observations on the duration, intensity and spread of the fire are discussed. Based on the results, models for simulation of fire exposure of radioactive materials packages in such fires are suggested.

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Determination of Fire Environment in Stacked Cargo Containers with Radioactive Materials Packages

1.0 Introduction

On June 2, 1973, the container ship *Sea Witch* collided with the tanker *Esso Brussels* in New York harbor[1]. The resulting container cargo fires have often been identified as among the worst to occur. Questions about the actual temperatures and heat transfer in and among the containers during this type of fire have been raised when shipments of hazardous cargoes are studied. The experiment described in this report attempts to answer some of the issues raised by the *Sea Witch* incident with a fire experiment that reproduces container cargo fire conditions. Thermocouples placed at various locations in a three-by-three stack of standard shipping containers placed over a pool fire provided information on the long term fire environment that could occur in containers during on-deck stowage on a container cargo ship. By locating combustible materials in some containers, conditions within and adjacent to the containers can be measured, and the potential for container-to-container spread in such fires was also assessed.

Sandia National Laboratories in Albuquerque, New Mexico conducted the fire test simulating on-deck stowage of a container cargo ship at the Coast Guard Fire and Safety Test Detachment located at Mobile, Alabama. The container cargoes, located in standard International Standards Organization (ISO) shipping containers, included both combustible materials and several real but empty radioactive material packages. The tests consisted of setting a fire in the existing pool fire facility on Little Sand Island and then monitoring the response of stacked ISO containers with simulated cargoes above the burning pool as shown in Figure 1.

Packages for shipment of radioactive materials meet relevant standards such as Title 10, Code of Federal Regulations, Part 71 (10CFR71) in the U.S. or International Atomic Energy Agency ST-1 for international shipments. Containers for larger "Type B" quantities of radioactive materials must be capable of surviving, without release of contents, a 30 minute fully engulfing pool fire typical of accidents that might occur during land transport. Fire conditions on containerized cargo ships probably differ significantly from the large, intense pool fires that are of concern for land transport. Comparison of the container ship fire environment to regulatory fire conditions will aid analysts assess the risks of sea transport of hazardous materials.

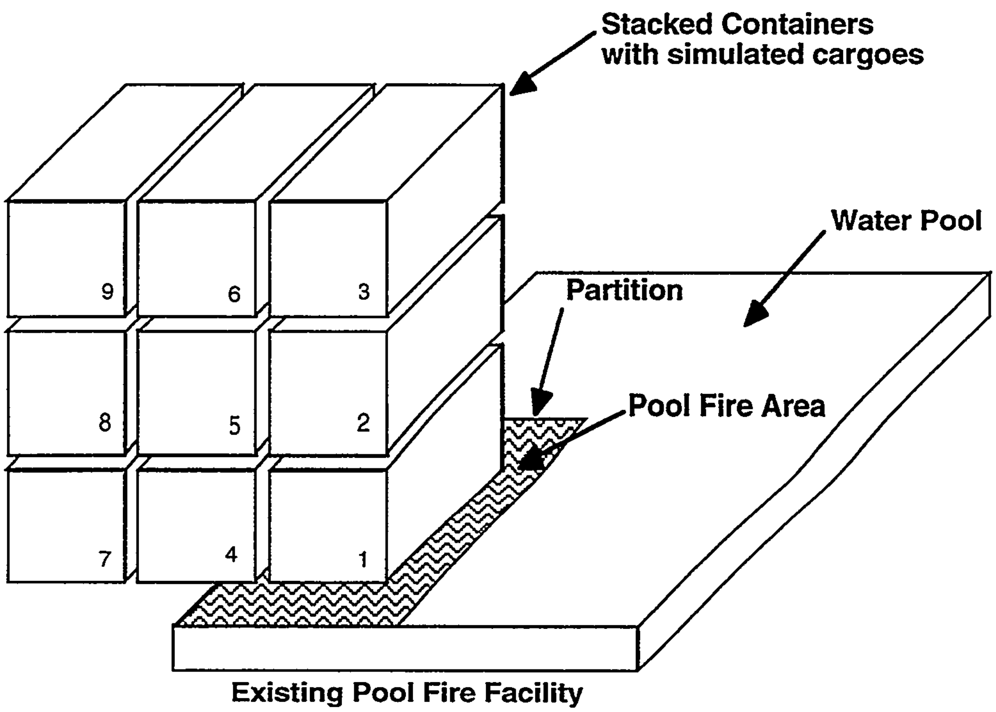


Figure 1. Schematic of container fire test.

Containers with designs standardized by the International Standards Organization are widely used for truck, rail, and sea transport. Measuring 2.4 m wide by 2.4 m high, the containers are available from various manufacturers in standard lengths of 6.1, 12.2, and 15.2 m. Lifting corners are provided as part of the standardized design to aid in loading and unloading the containers. Most containers used for packaged goods are constructed from steel, but aluminum and fiber glass materials have also been used. Because of their maintainability and ruggedness, the steel containers predominate over the other types of construction. Specialized designs with the standard lifting corners are also available in forms such as cylindrical tanks mounted inside the standard frame and hermetically sealed containers.

Construction components of a typical container are shown in Figure 2. Note that the floors are typically wood planks or plywood sheets laid on steel cross members. Use of wood allows for some compliance and cushion during loading and unloading, and is readily replaceable without special tools. In some designs, planks or sheets may alternate with steel skid plates. Wood floors are typically 20 to 25 mm thick. All containers used for the tests conformed to the ISO standard although many types of construction were employed.

The tests described in the report are intended to be representative of conditions that could occur during an on-deck fire involving containers stacked as shown in Figure 3. This configuration was chosen as the stowage location with the maximum availability of oxygen and the least protection

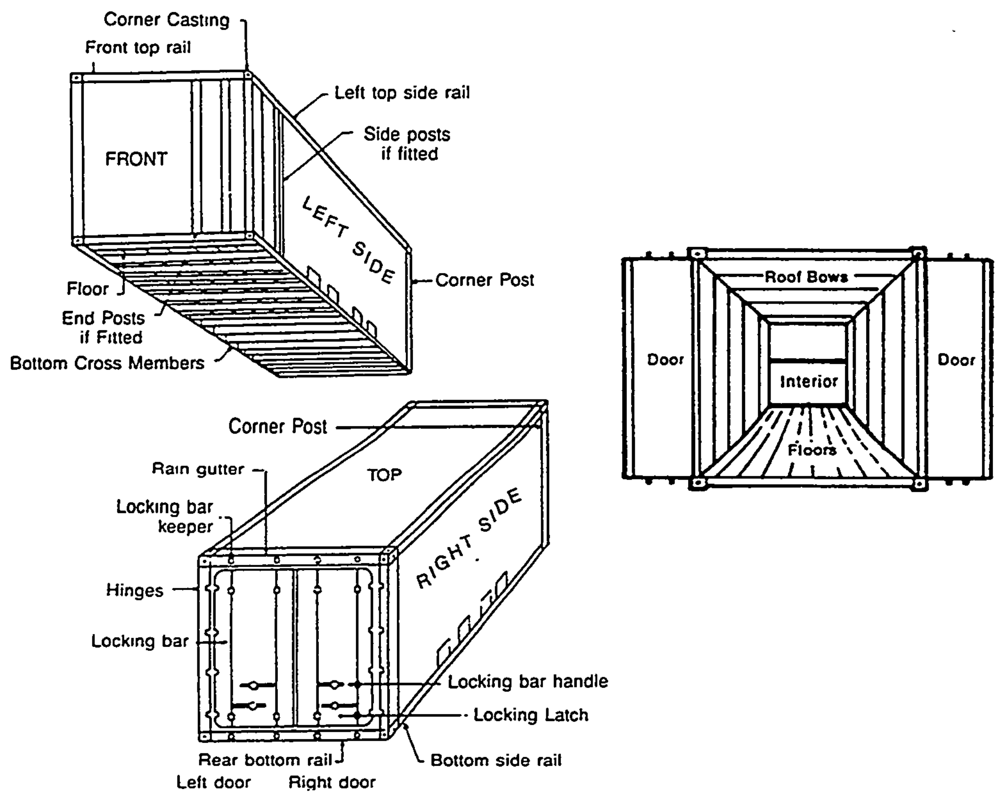


Figure 2. Typical construction of International Standards Organization container.

from ship structures. Typical configurations involve stacking containers two or three high on the deck as shown in the photograph.

2.0 Test Arrangement and Instrumentation

2.1 Test Geometry and Description

The main objective of the experiments was to measure temperatures and the thermal environment during a fire involving containerized cargoes of simulated and real radioactive materials packages in a configuration typical of on-deck stowage. Based on results from the *Sea Witch* accident investigation[1], the on-deck environment was expected to be more severe than below-deck stowage, probably because of the ready availability of oxygen to support combustion. The experimental results are intended for use in future documents such as Environmental Impact Statements and Environmental Assessments for particular shipments or shipping campaigns. An additional objective of the experiments is to quantify typical container fire conditions and to provide a comparison between the fully engulfing open pool fire associated with land transport accidents and the fires typical of marine transport.

A three-by-three array of 6 m long ISO containers of various types was exposed to a large JP-8 pool fire at the existing 15 m x 15 m pool on Little Sand Island as shown in Figures 1 and 4. Previously used commercial containers were purchased specifically for this test. The containers were numbered for test purposes as shown in Figure 1. The array was placed in a configuration typical of sea transport conditions on container ships. One stack of containers was directly located over the fire to measure that fire environment, one stack straddled the edge of the pool while the final stack was adjacent to the fire to enable measurement of possible container-to-container fire spread. The interior of the containers was instrumented and loaded with simulated combustible cargo such as newspapers, scrap lumber, and cardboard boxes. Steel pipe calorimeters that simulated Type B packages were placed in three of the containers to allow heat transfer to the package to be measured. After the pool fire burned out at approximately one hour, the container array was monitored to determine duration and spread of fires in the combustible cargoes and containers adjacent to the pool. To conserve the amount of fuel needed for the test, a welded partition was used to limit burning area to a 6 m x 9.8 m section of the existing 15 m x 15 m pool.

2.2 Cargo Manifest

Containers in the stack that did not contain simulated or real radioactive materials packages were filled with various combustible materials as shown in Figure 5. The figure schematically represents a view of the container stack as viewed from the east side of the stack as shown in Figure 6.

2.3 Fuel and Quantity

Because of its ready availability, JP8 jet fuel was used for the pool fire. For the approximate one hour fire duration, 24.4 cm of fuel was floated on the surface of the water in the 6 m x 9.8 m section of the pool. Approximately 14.4 m^3 of fuel was required to complete the burn.

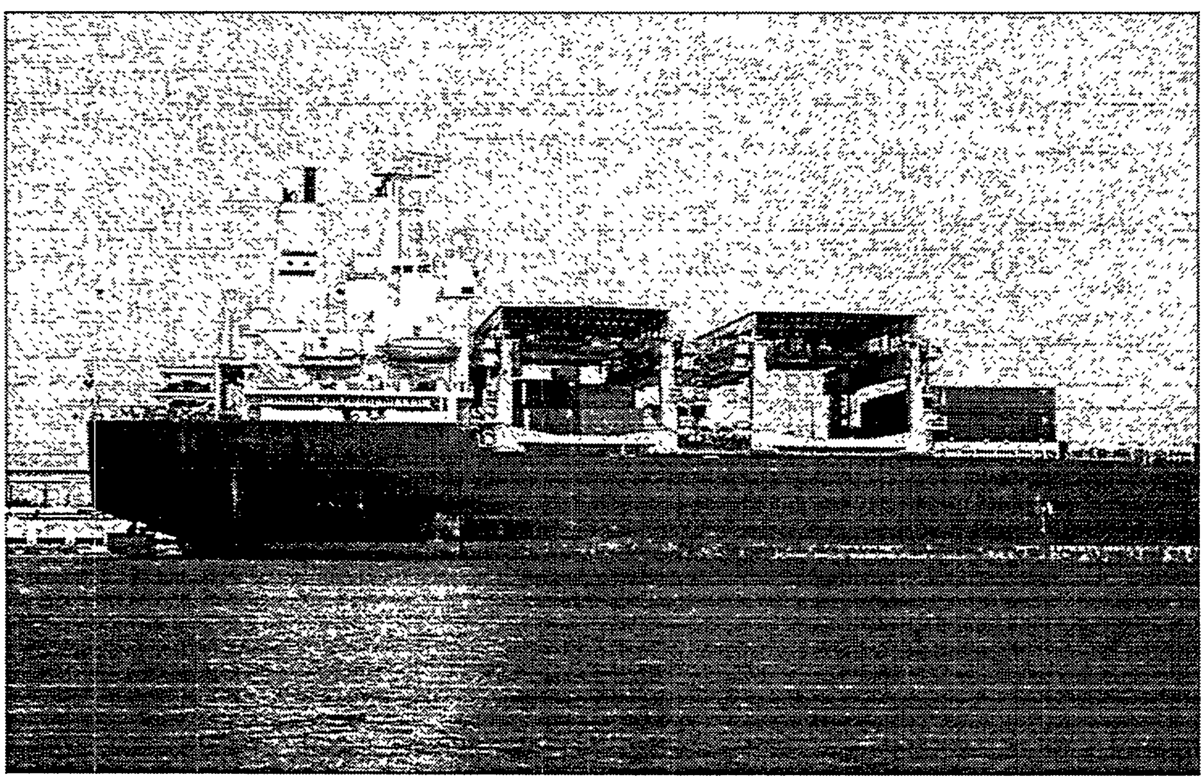


Figure 3. Typical on-deck stowage of containers.

2.4 Thermocouple Type and Locations

Each of the nine standard shipping containers was instrumented with seven thermocouples at the approximate locations shown in Figure 7. The first number of the thermocouple number refers to the container numbers shown in Figure 1. More precise locations of thermocouples are given in Appendix A. Commercial type K (chromel-alumel), inconel sheathed, 1.6 mm outside diameter thermocouples with magnesia insulation were used throughout the experiment. Thermocouples were routed to be away from the flame zone where possible.

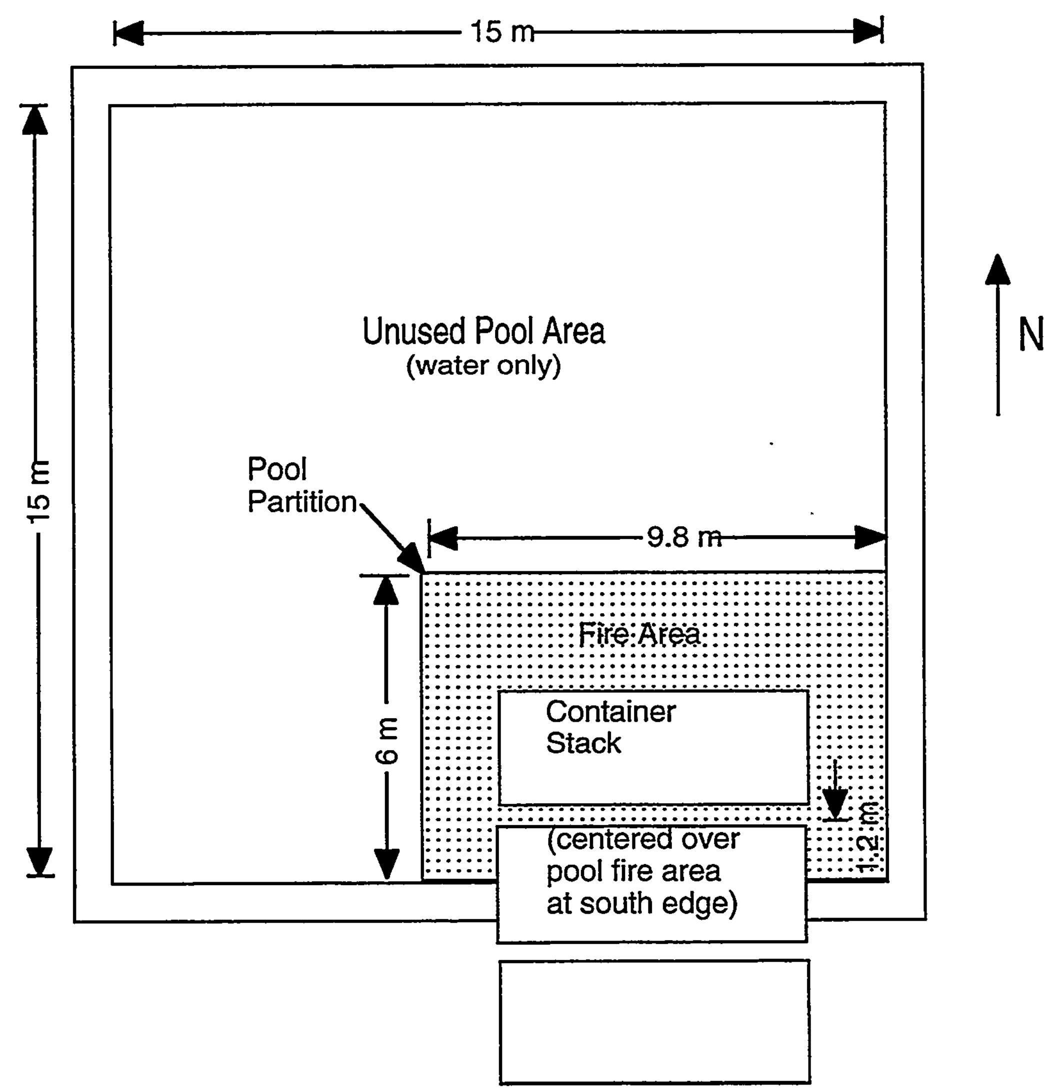


Figure 4. Plan view of test arrangement.

Paper Bale 0.6 Tonne (on fire side)	SS Calorimeter 0.762 m diam. 4.6 m length	Paper Bales 2.6 Tonne Pipe Calo- rimeter 0.61 m diam. 0.93 m length
Paper Bale 0.6 Tonne (on fire side)	Paper Bales 2.3 Tonne	Packagings: AT400A Safkeg AT400R Dummy 55 gal. drums Pipe Calorimeter
Paper Bale 0.6 Tonne (on fire side)	Wood Pallets 1 Tonne	Cardboard Box Bales 1.3 Tonne

View from east (door) side of stack

Fire Location

Figure 5. Contents of containers during experiment.

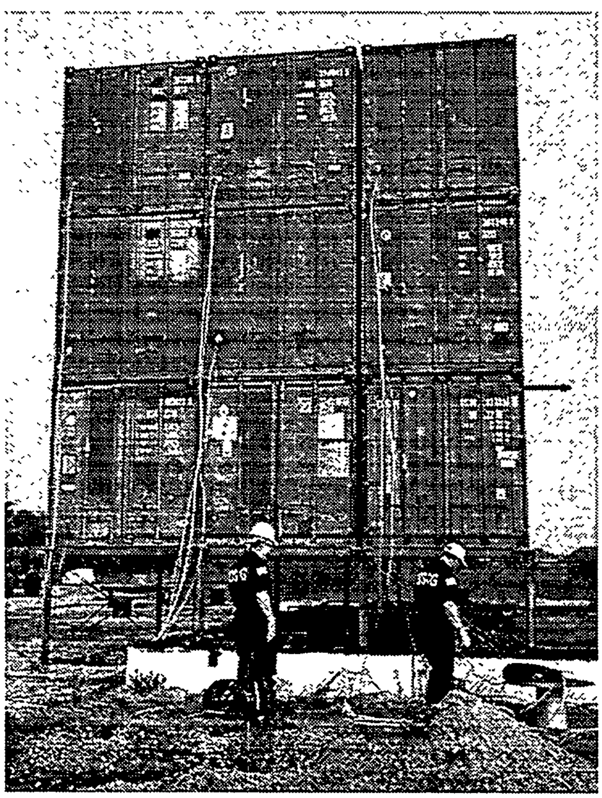


Figure 6. Completed container stack as viewed from east side.

2.5 Calorimeters

The calorimeters simulating a radioactive material shipment were constructed in two configurations. A single stainless steel calorimeter located in Container 6 was constructed from nominal 30 inch diameter, 0.25 inch wall, Type 304L stainless steel as shown in Figure 8. The calorimeter was instrumented with 15 Type K sheathed thermocouples with 0.063 inch outside diameters placed as shown in Figure 8. To block internal thermal radiation, portions of the interior of the calorimeter were insulated with commercial insulation. The exterior of the calorimeter was coated with Pyromark flat black paint to enhance surface absorptance. The surface absorptance of the calorimeter and its coating was estimated from measurements from similar surfaces tested at Sandia.

Two additional calorimeters located in Containers 2 and 3 were constructed from schedule 60 mild steel pipe 24 inches O.D. by 5 feet long with thermocouples installed at locations shown in Figure 9. The end plates are made of one inch mild steel plate. These calorimeters were also instrumented with 12 Type K sheathed thermocouples with 0.063 inch outside diameter each mounted on the pipe interior as shown in Figure 9.

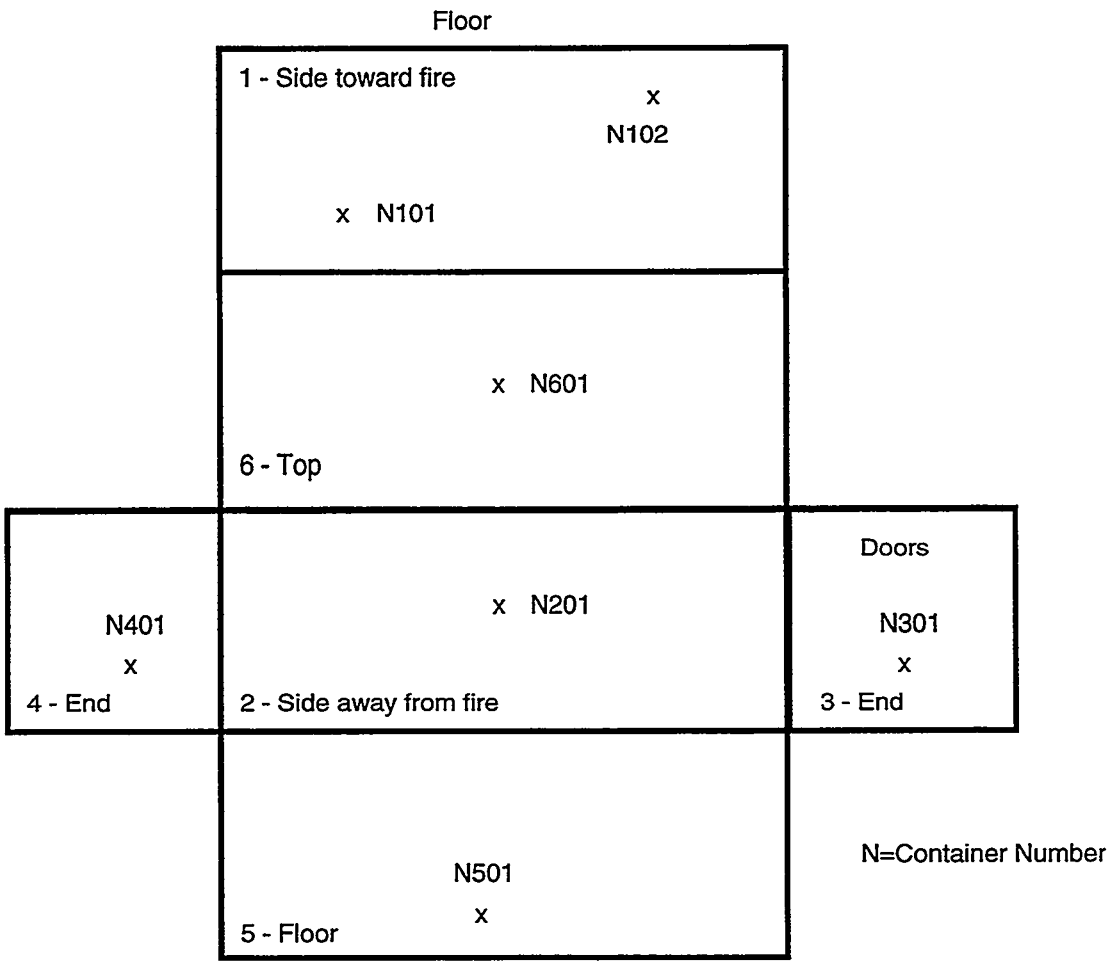


Figure 7. Approximate locations for thermocouple attachment. The sketch shows the interior of a container unfolded in a manner similar to a cardboard box.

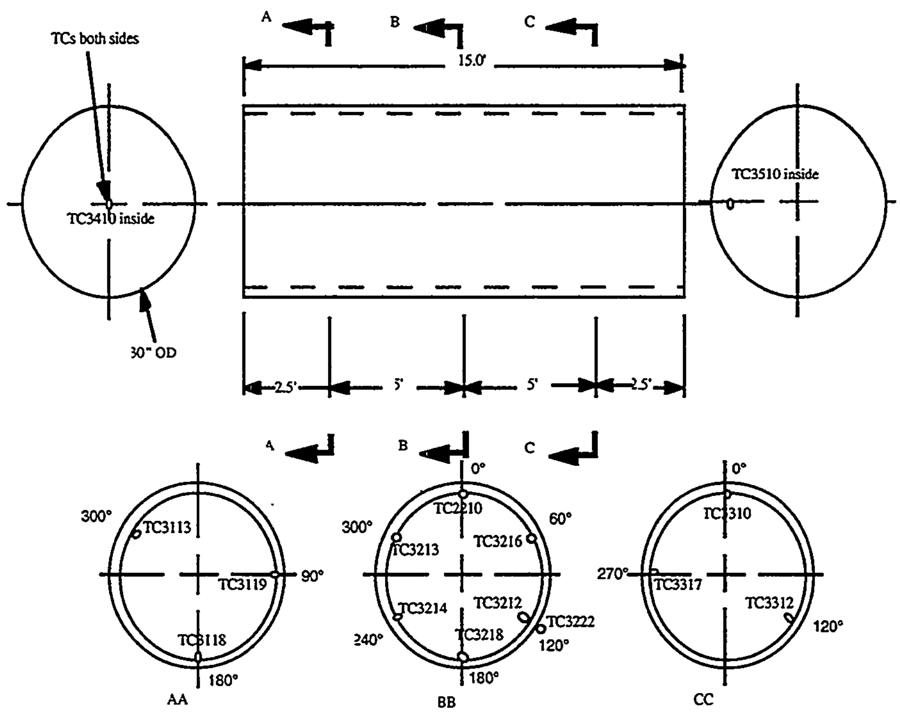


Figure 8. Calorimeter 3 thermocouple locations.

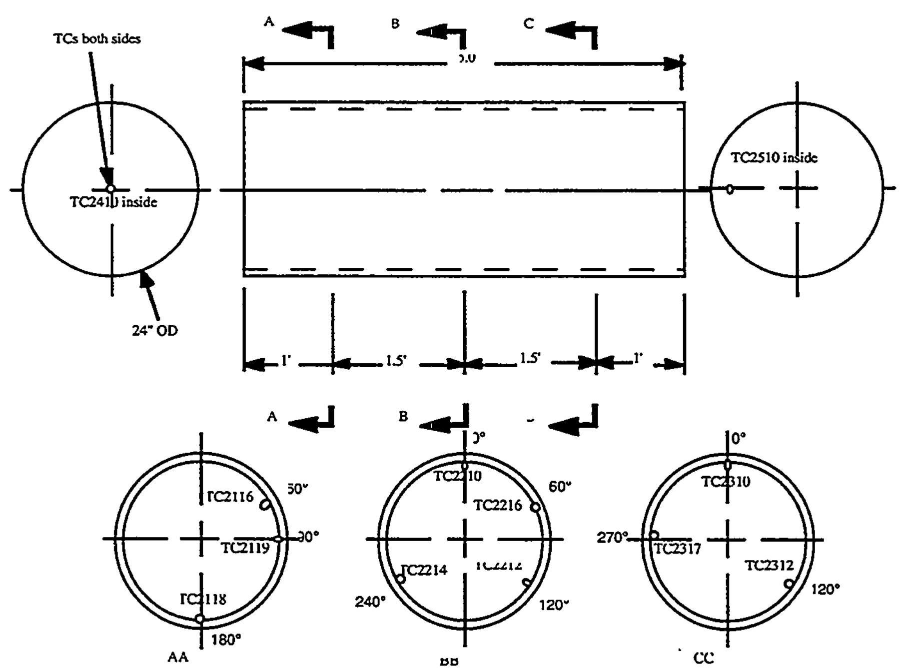


Figure 9. Calorimeters 1 and 2 thermocouple locations.

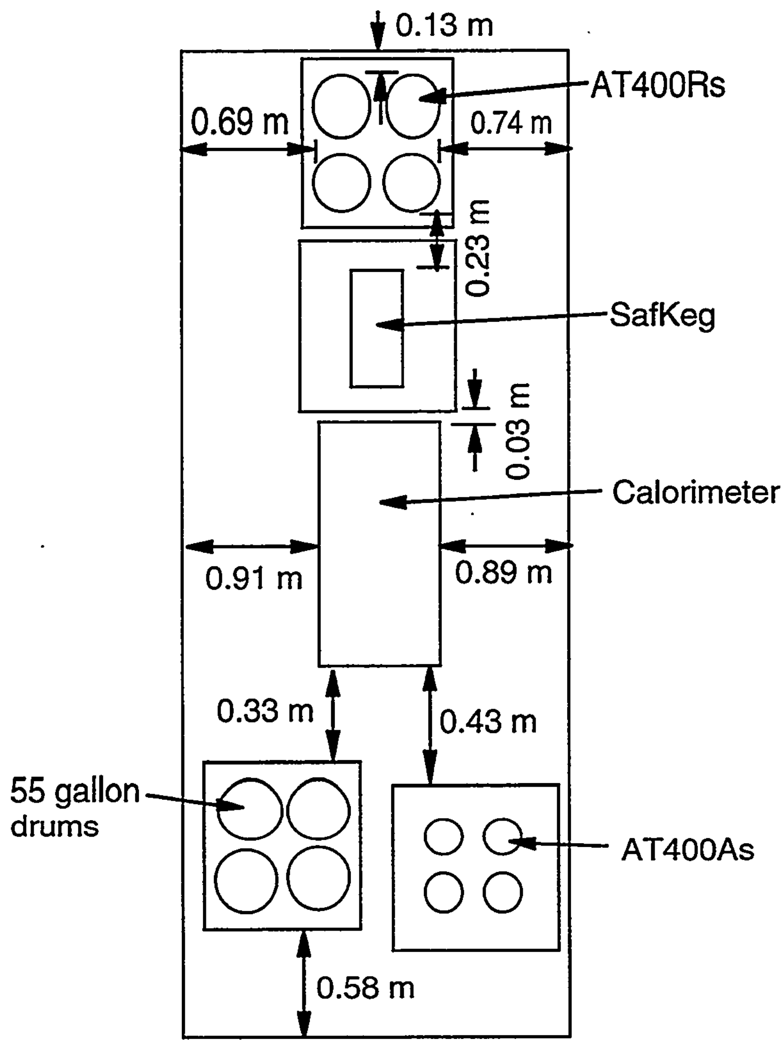


Figure 10. Plan view schematic arrangement of packages in Container 2.

2.6 Other Packages

Container No. 2, as shown in Figures 1 and 5, contained several actual small radioactive materials packages as well as a pipe calorimeter. Packages included four AT400R prototype containers and four AT400A prototype containers used for transport of weapons components, as well as four nominal 55 gallon drums fitted with Celotex inserts and interior pipe components similar to those used for storage of weapons components at Rocky Flats. A prototype SafKeg container, manufactured by Croft and provided by Los Alamos National Laboratory was also included. A sketch of the general arrangement of the packages on wood pallets is shown in Figure 10.

2.7 Directional Flame Thermometers

Over the pool fire and in a gap between the stacks of containers, Directional Flame Thermometers (DFTs) based on a design from Burgess and Fry [2] were used to estimate the temperatures of the engulfing flames. These devices, which resembles a vegetable can, have thin metal ends that rapidly approach flame temperatures. Thermocouples attached on the inside of the thin metal ends provide an estimate of flame temperatures in the direction that the end faces in the fire. The cans are filled with insulation to prevent internal heat transfer within the DFT.

Four DFTs, two on each side of Container 2, were inserted at the level of the container floor. On the fire side the two DFTs were wired to 1 m long channels that placed them over the fire and away from the container. On the container side away from the fire, the DFTs were mounted between Containers 2 and 5 in the150 mm wide gap between the first and second container stacks.

2.8 Temperature Sensitive Labels

Temperature sensitive labels that change colors to indicate the maximum temperature reached were attached to the interior surfaces of radioactive materials packages used in the experiment. The labels used were Tempilabel Series 4 labels that covered a temperature range of 38 to 232°C. After the test, the packages were reopened and the maximum temperatures recorded. Locations where labels were attached are shown in Appendix C.

2.9 Container Weight Measurements

For weight measurements, the containers were supported from a crane with a load cell attached to the crane hook. Containers were weighed empty, loaded, and after the fire. The weight differences were used to estimate the container load and the amount of material combusted during the experiment.

3.0 Results

The pool fire was ignited at 8:18 AM on July 30, 1997. Burn duration of the pool fire was 54 minutes. Shortly after the start of the test, the suction hose to the pump that provided flow through the steel support channels failed, leading to a loss of cooling water for the entire structure that supported the containers over the pool. At 16 minutes after the start of the test, the steel supports sagged, dropping containers 2, 3 and 6 into the unburning portion of the pool. The remaining containers stayed in their original position for the duration of the burn. The final configuration for the containers after the collapse is shown in Figure 11.

Despite the unanticipated collapse, good data continued to be obtained for Container 2 and the containers that remained in the stack. Data for Containers 3 and 6 were lost at the 16 minute point when the thermocouple leads were severed during the collapse. Data were monitored for 24 hours to determine if fires rekindled after a period of time, and to determine the severity of such fire conditions. Wind speed and direction at ground level during the morning of the fire are shown in Figure 12. Wind during the pool fire was generally from the northeast, with occasional swings to the northwest. Wind velocity during the fire was between 1 and 2 m/s.

Figure 11. Container stack after fire showing final configuration. Left to right, Containers 2, 6 and 3 are seen to the right of the stack.

3.1 Container Thermocouples

Results from the thermocouples mounted on the container walls showed a wide range of behavior indicative of the container contents and the location in the stack. Typical results from Containers 1, 2, 5, and 8 (see Figure 1) will be presented here, while remaining plots will be presented in Appendix B for completeness. The plots are divided into three segments covering the initial pool fire, 2 to 14 hours after ignition, and the overnight period covering up to 24 hours after ignition.

Results from Container 1, which contained baled cardboard boxes, are shown in Figures 13, 14, and 15. The quick initial temperature increase of the thermocouples indicates that the thin metal walls of the containers respond rapidly in the fire. The thermocouple numbers shown in the legends correspond to the locations shown in Figure 7. Temperatures for the walls, floor and roof of the container quickly reached temperatures between 800°C and 1000°C during the one hour pool fire, then decreased after the fire. Noise appeared in all the thermocouple data between 10 and 15 minutes after fire ignition. Data from this 5 minute period have been removed from the plots. The most likely source for the noise is thermocouple shunting errors that are caused when the thermocouple manufacturer uses industrial grade magnesia (MgO) rather than 99 per cent pure magnesia as insulation inside the inconel sheath of the thermocouples. Industrial grade magnesia loses its electrical resistance at much lower temperatures than the 99 per cent pure magnesia that is normally used in high-temperature thermocouples. When thermocouple leads are exposed to high temperatures, the lower grade magnesia fails as an electrical insulator, shorting the thermocouple wires to each other and to the inconel sheath. This forms several additional thermocouple junctions along the length of the thermocouple leads, and leads to erratic signals. Once the fire subsides, the leads cool, and the magnesia regains its electrical insulation properties, the thermocouple signals return to normal. The substitution of industrial grade magnesia can be either intentional, to save cost or maintain schedule, or unintentional when the magnesia supplier fails to provide the correct material to the thermocouple manufacturer.

After the fire, with the exception of a brief flare-up about 6 hours after ignition, temperatures dropped significantly from the 400°C range to the 100°C range (see Figure 14). This apparently reflected the container internal conditions as the cardboard box bales inside the container continued to burn after the pool fire finished burning. For the overnight period, Figure 15 shows that most temperatures of the container walls were close to ambient night conditions for the Mobile site, with the exception of the floor thermocouple that indicated continuing smoldering of the remainder of the cardboard box bales.

Results from Container 2 that contained various radioactive materials package are shown in Figures 16, 17 and 18. These data demonstrate the effect of the collapse of the containers into the pool. The 900°C maximum temperatures for thermocouple TC2501 indicates that the wood floor of the container, covered with a steel plate for the test, ignited during the pool fire, and continued to burn after the pool fire stopped burning. The temperatures of 550°C for TC2201 are consistent

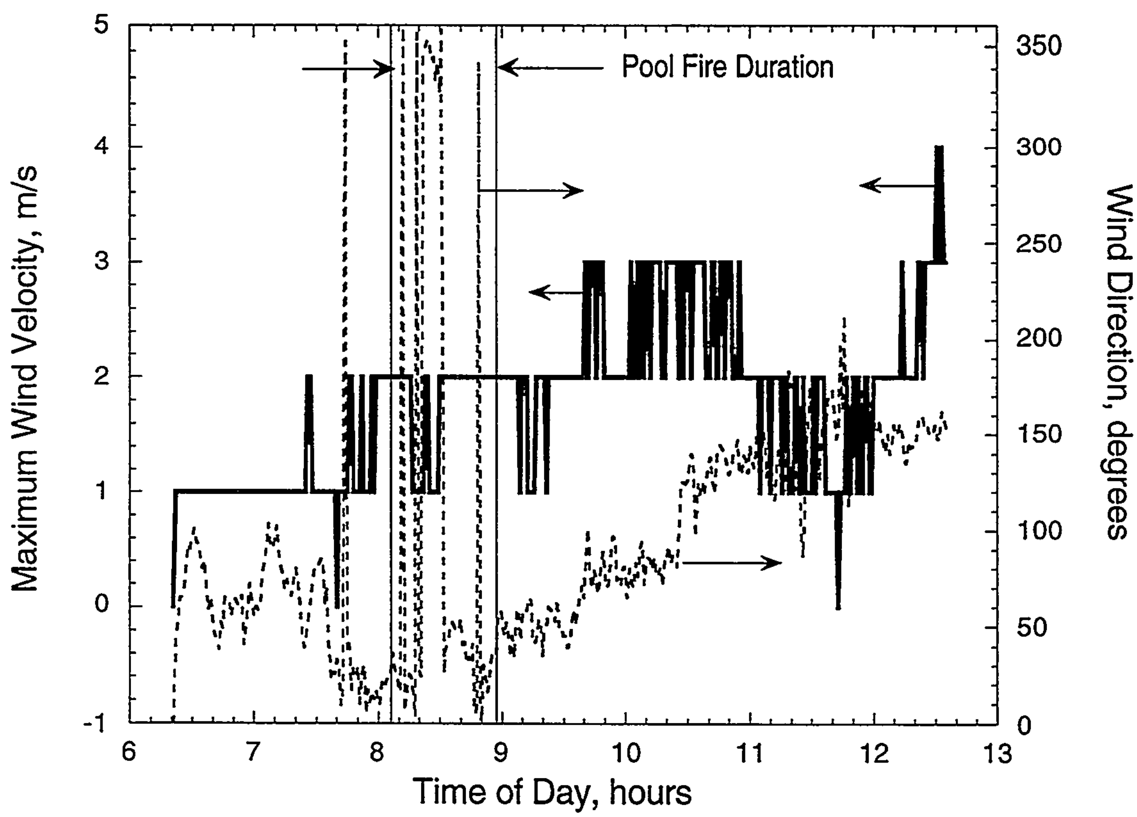


Figure 12. Wind speed and duration for the morning of the fire.

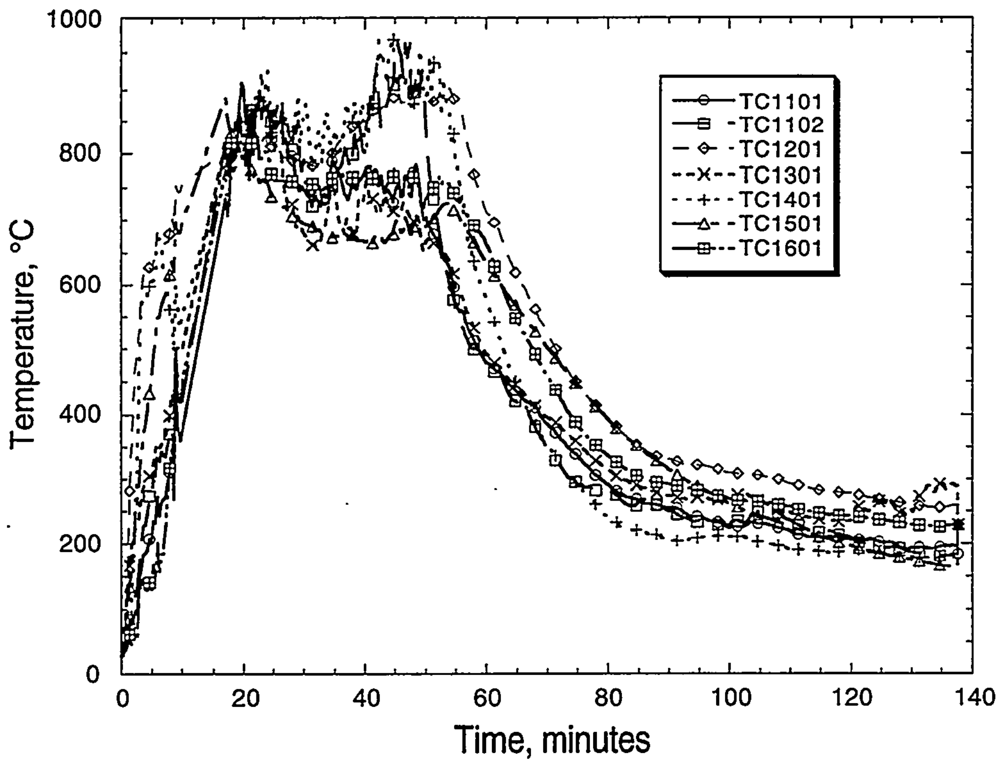


Figure 13. Container 1 thermocouple results for period during and following pool fire.

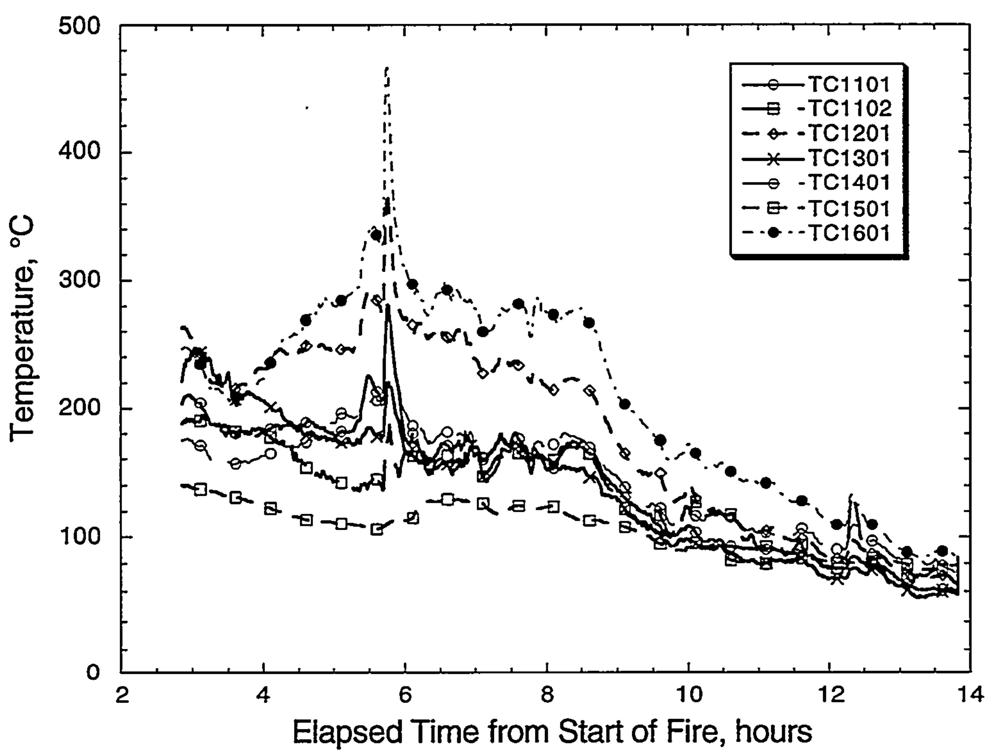


Figure 14. Container 1 temperatures between 2 and 14 hours after ignition.

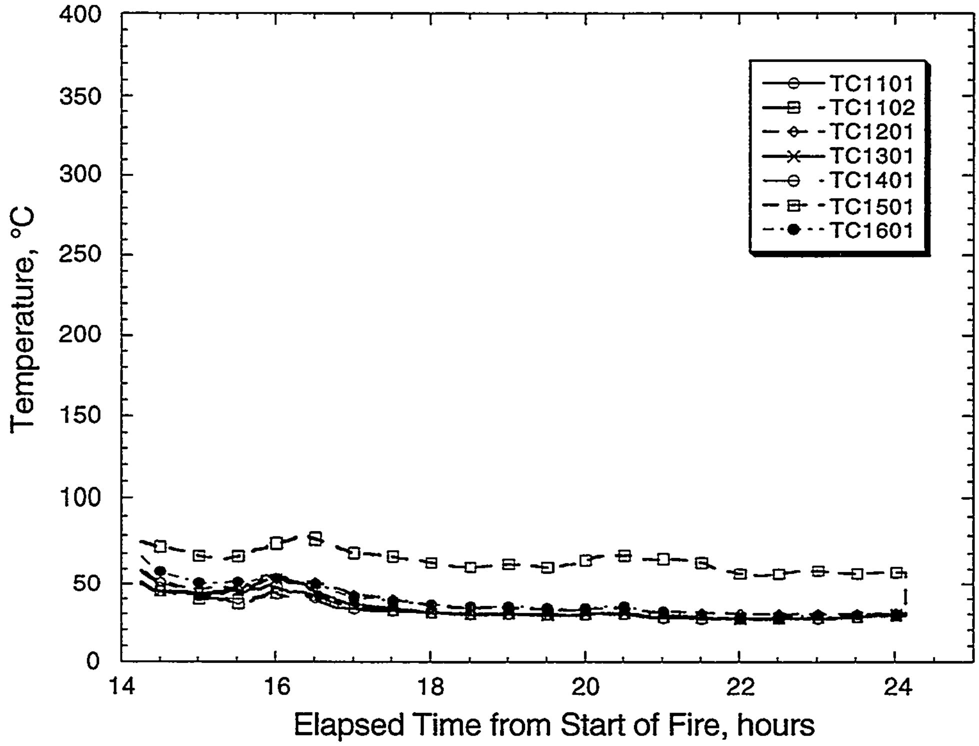


Figure 15. Container 1 temperatures during night after pool fire.

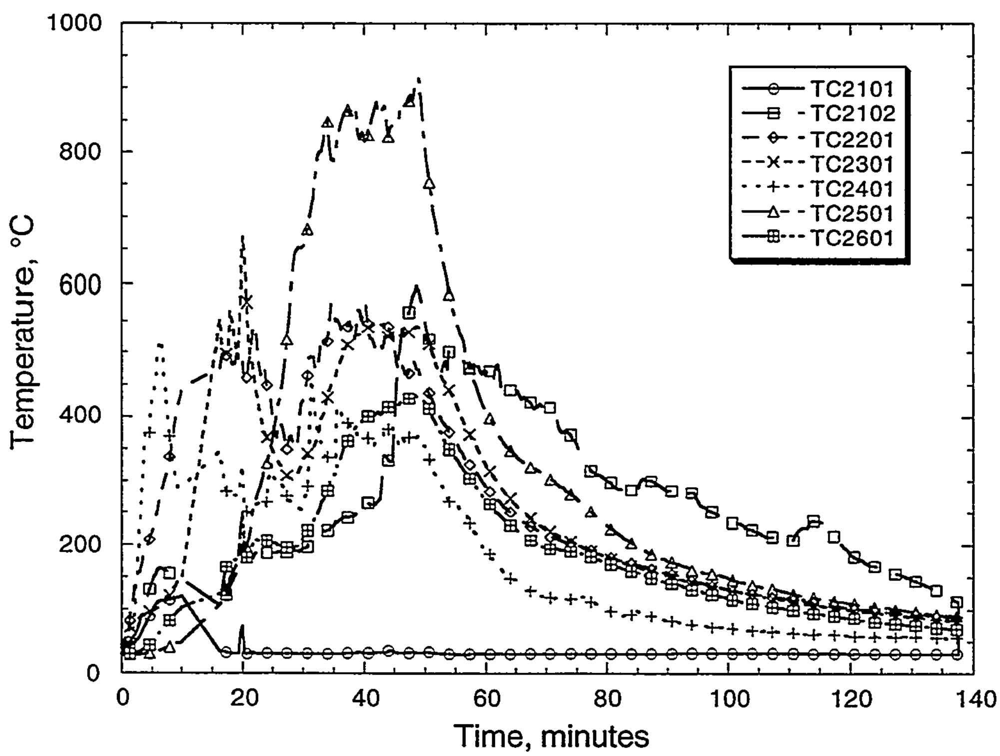


Figure 16. Container 2 thermocouple results for period during and following pool fire.

with the location of the thermocouple on the wall of the container that faced upward with a full view of the fire after the collapse. The relatively high temperatures for TC2102 indicate that the thermocouple wall location, although initially on the fire facing wall, was not submerged under water during the pool fire after the collapse. Figure 17 shows some minor flare-up activities about 8 hours after the start of the fire, but Figure 18 shows consistent cooling during the overnight period.

Container 5 which contained three paper bales remained on the stack after the collapse. Wall thermocouple results from this container are shown in Figures19, 20, and 21. Despite being partially shielded from the pool fire by other containers, the walls of the containers reached peak temperatures in the 900 to 1000°C range. The trace from thermocouple TC5501 indicates that burning in the vicinity of the container floor continued after the pool fire finished. The burning continues with temperatures recorded in the 300 to 400°C range throughout the night. During unstacking operations the next morning, the container was not weighed because it was not possible to attach the cables to lift the container for weight measurements.

The results for Container 8 shown in Figures 22, 23 and 24 are typical for the containers in the stack not over the pool fire. During experiment design, doubts were expressed that the contents of the containers would be ignited. Experimentally, all containers ignited and burned their combustible contents fully. After the typical 500 to 900°C wall temperatures for all thermocouples during the pool fire, the roof and floor thermocouples TC8501 and TC8601 continue hot after the fire, indicating that the wood floors and cargoes of both Container 8 and Container 9 are burning. Once the floors burn through, then oxygen can freely enter the container to allow combustion to continue. The floors and cargo continue to burn until approximately 6 hours after ignition, and then the containers slowly cool overnight. Post fire inspection showed that the entire floor of Container 8 had burned.

3.2 Calorimeter Results

Although Calorimeter 1 was in a container that tumbled into the pool during the fire, the thermocouple leads remained intact and gave data throughout the experiment. Thermocouple leads to Calorimeter 2 and 3, which were located in Containers 3 and 6, fractured when the container stack collapsed. Since only inconclusive early time data are available for Calorimeters 2 and 3, the data are not included in this report.

Calorimeter 1was roughly centered in Container 2 as shown in Figure 10. The calorimeter was welded to steel support plates that were in turn welded to the steel plates covering the floor of the container. After the collapse, the calorimeter remained in its original position relative to the floor of the container. Since the container was on its side, this means that the container wall that was originally away from the fire was exposed to radiant energy from the fire after the collapse (See Figure 11). This change in fire exposure is reflected in the thermocouple data.

Figures 25, 26 and 27 show the temperatures in calorimeter 1 recorded during and immediately after the pool fire. In the original configuration the thermocouples located at an angle of 90 degrees from the top of the calorimeter faced directly toward the fire. After the collapse, thermocouples on

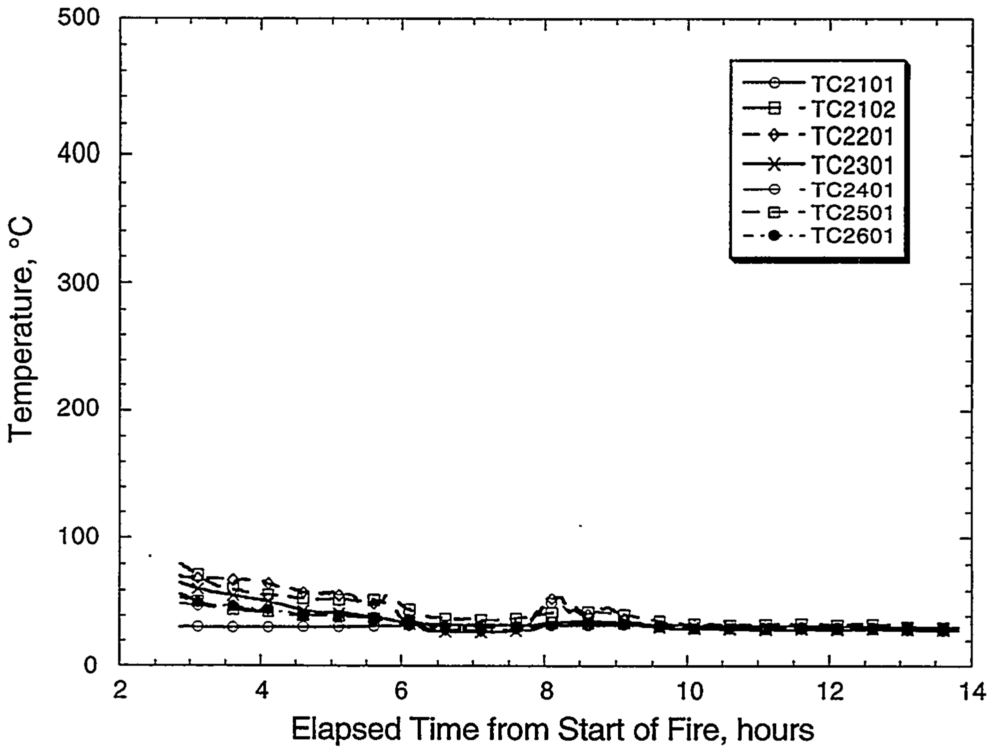


Figure 17. Container 2 temperatures between 2 and 14 hours after ignition.

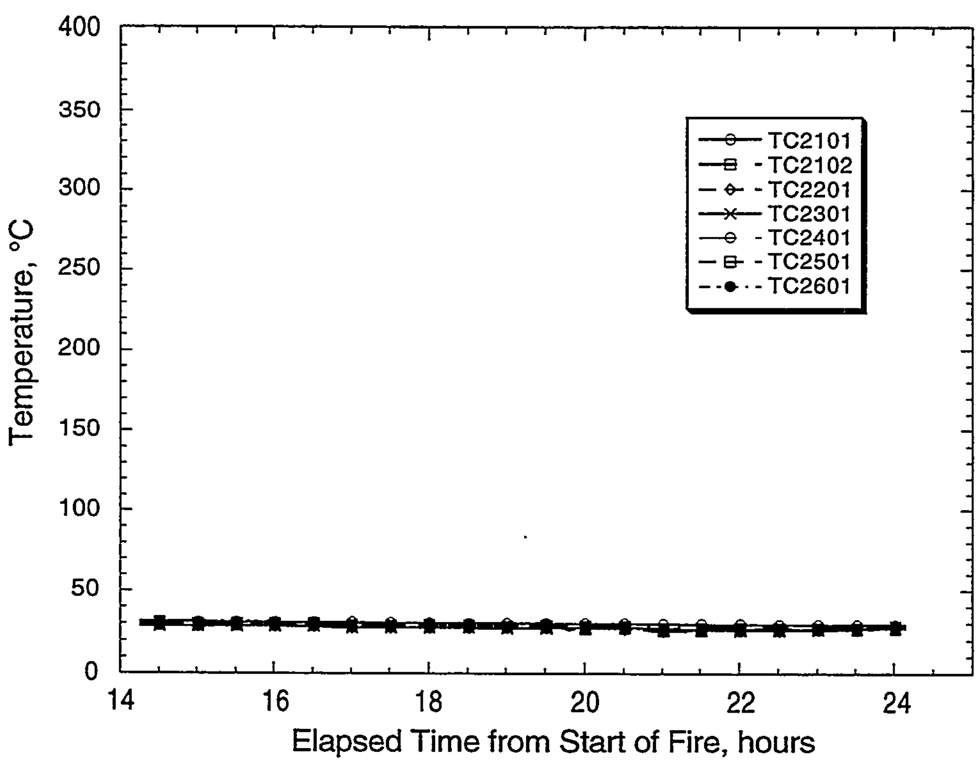


Figure 18. Container 2 temperatures during night after pool fire.

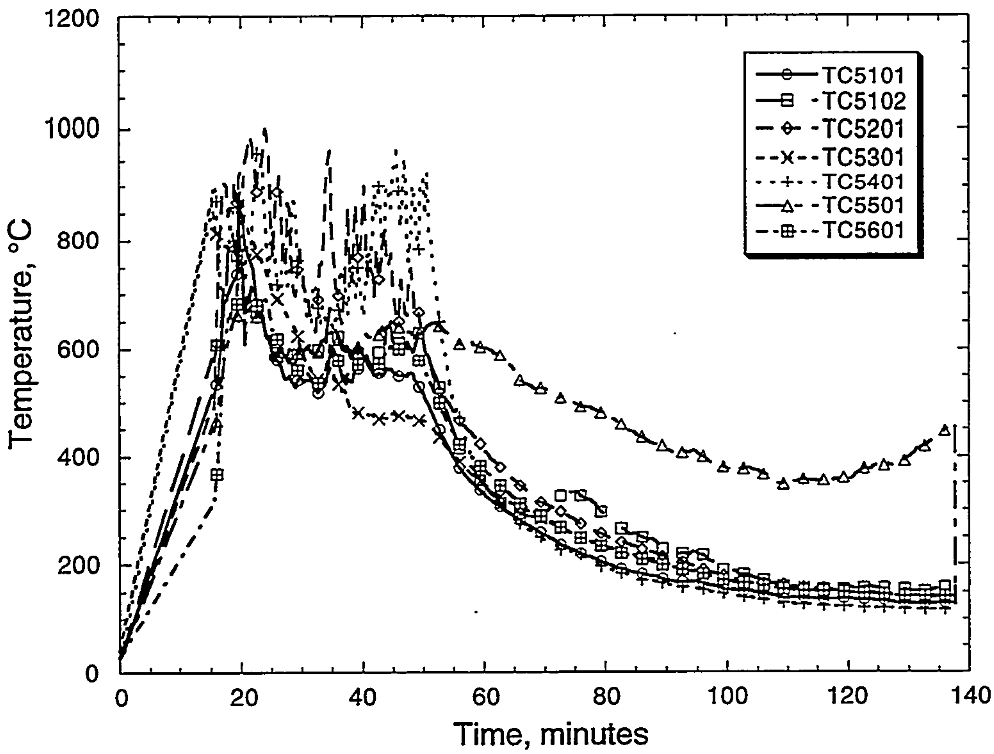


Figure 19. Container 5 thermocouple results for period during and following pool fire.

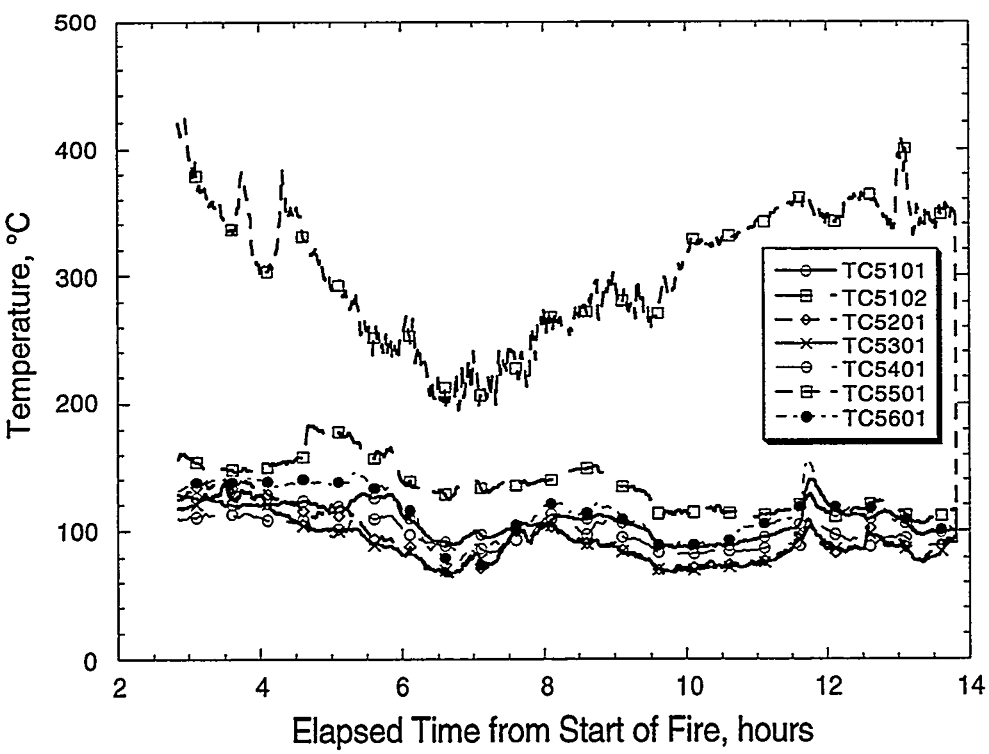


Figure 20. Container 5 temperatures between 2 and 14 hours after ignition.

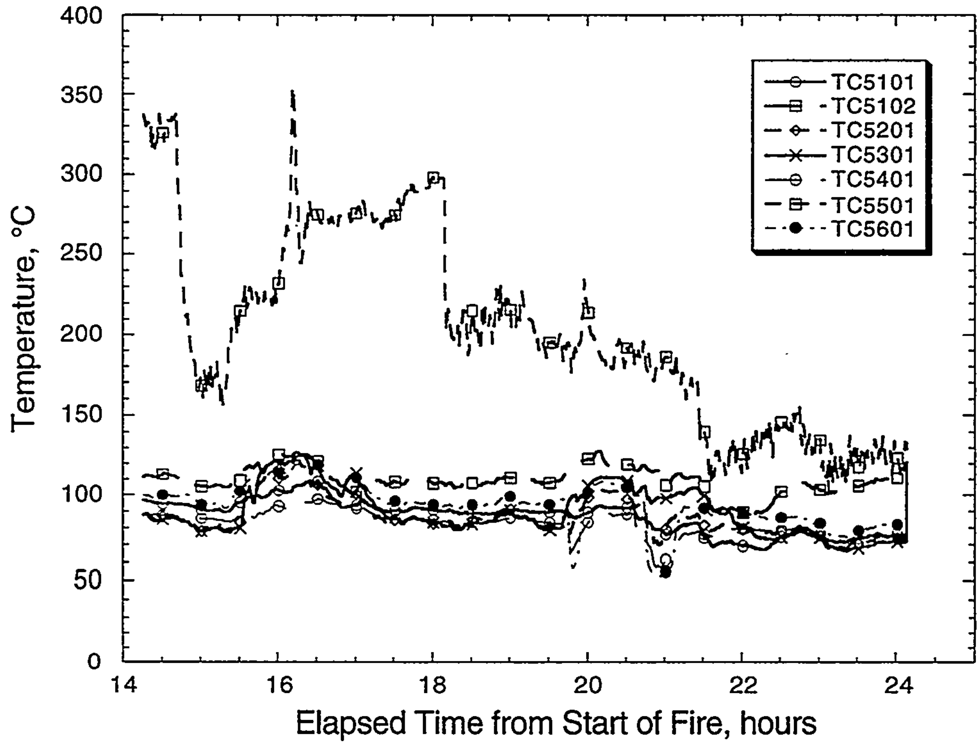


Figure 21. Container 5 temperatures during the night after pool fire.

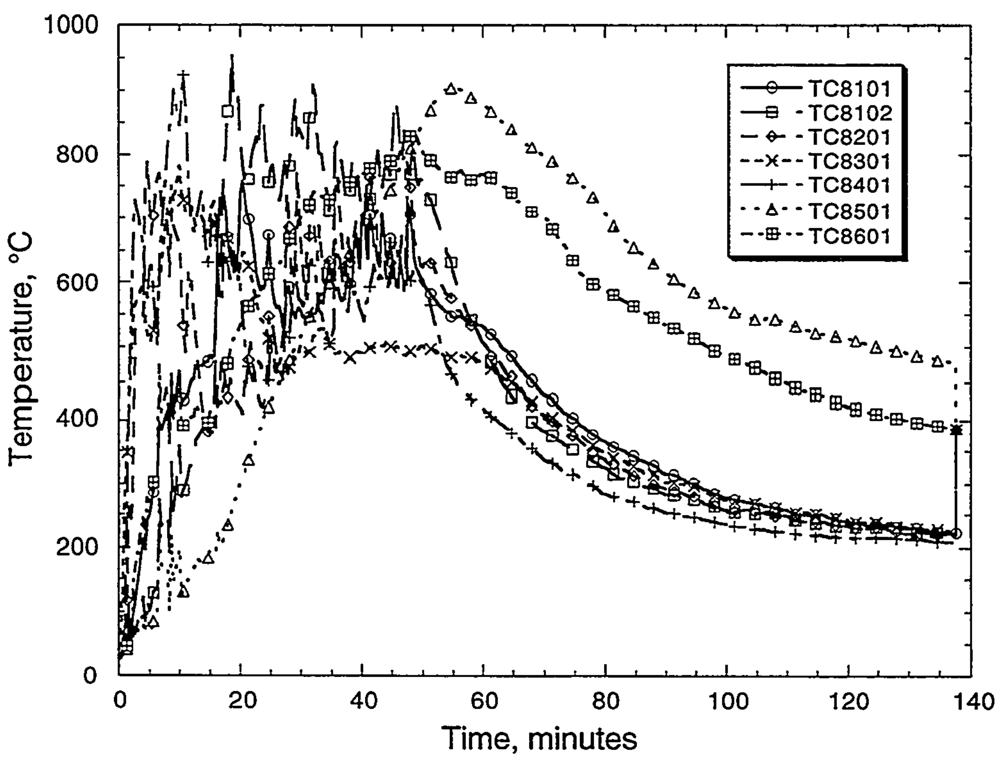


Figure 22. Container 8 thermocouple results for period during and following pool fire.

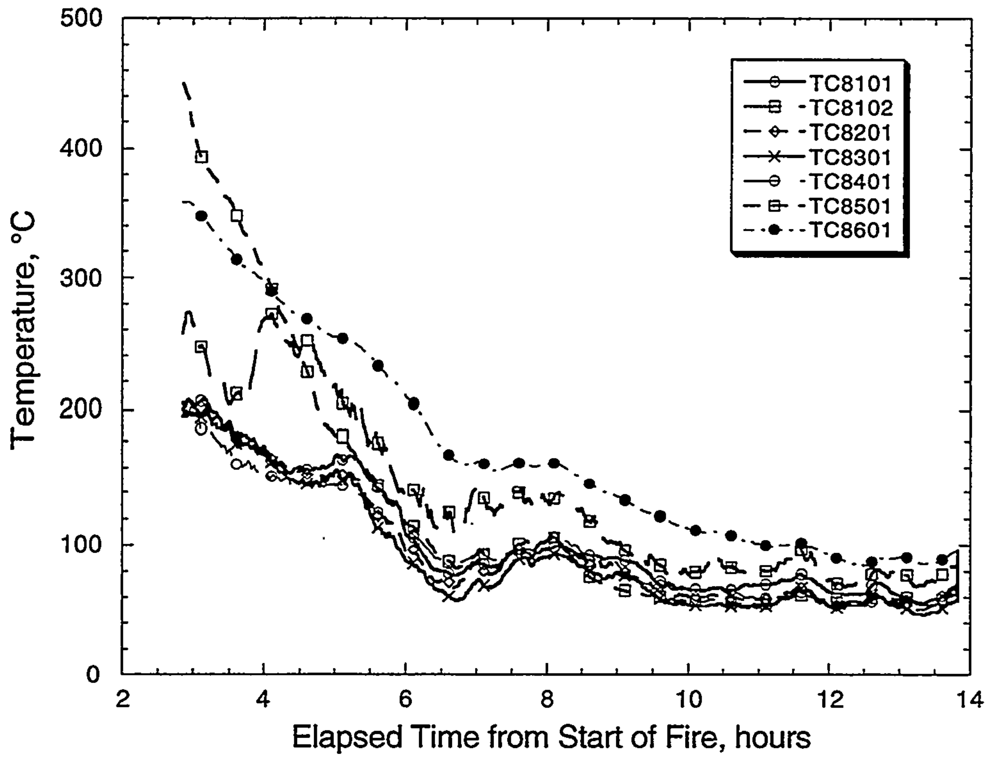


Figure 23. Container 8 temperatures between 2 and 14 hours after ignition.

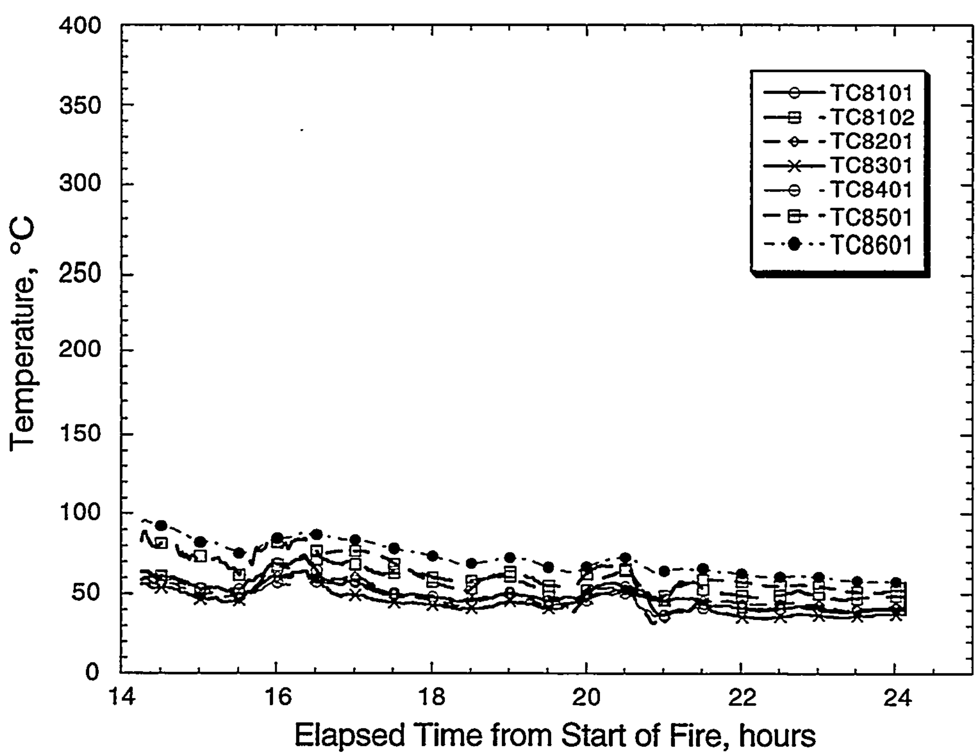


Figure 24. Container 8 temperatures during night after pool fire.

the opposite side of the calorimeter faced the hot floor and the pool fire. Despite the collapse, calorimeter temperatures approached 500°C during the pool fire, but fell quickly afterward.

3.3 Package Results

Temperatures in the various empty radioactive materials packages in Container 2 were measured by both thermocouples and temperature sensitive strips. After the collapse of the container stack, the thermocouples continued to provide data. Temperatures from the three thermocouples attached to the packages are shown in Figure 28 and the temperature strip results are summarized in Table 1. Despite the collapse, surface temperatures of the packages in some locations approached 500°C. A trend noticed in the Container 2 wall temperatures is also exhibited in the package thermocouples. As with the container wall, packages at the west end of the container, the end opposite the doors, tended to heat to a higher temperature. This indicates that even after the collapse, that end of the container continued to be exposed to the flames.

Table 1: Temperature Strip Results

Package	Outside T (°C)	Layer 1 T (°C)	Layer 2 T (°C)	Inside T (°C)
RFD-1	obscured			54
RFD-2	<188			60
RFD-3	>260			66
RFD-4	<188			60
AT400R-1	166	54		<38
AT400R-2	<171	54		<38
AT400R-3	obscured	<38		N/A
AT400R-4	143	54		N/A
AT400A-1	166			77
AT400A-2	>343			>166
AT400A-3	>316			>121
AT400A-4	110			<38
SAFE-KEG	121	49-54	28	28

After 16-minutes, ISO Container 2 became partially immersed in the pool when the support structure collapsed. Many of the packages inside the container were then immersed or partially immersed in the pool water. Packages identified as AT400A-2 and AT400A-3 clearly received a high level of exposure to heat from the pool fire. Their peak internal temperatures were 166°C and

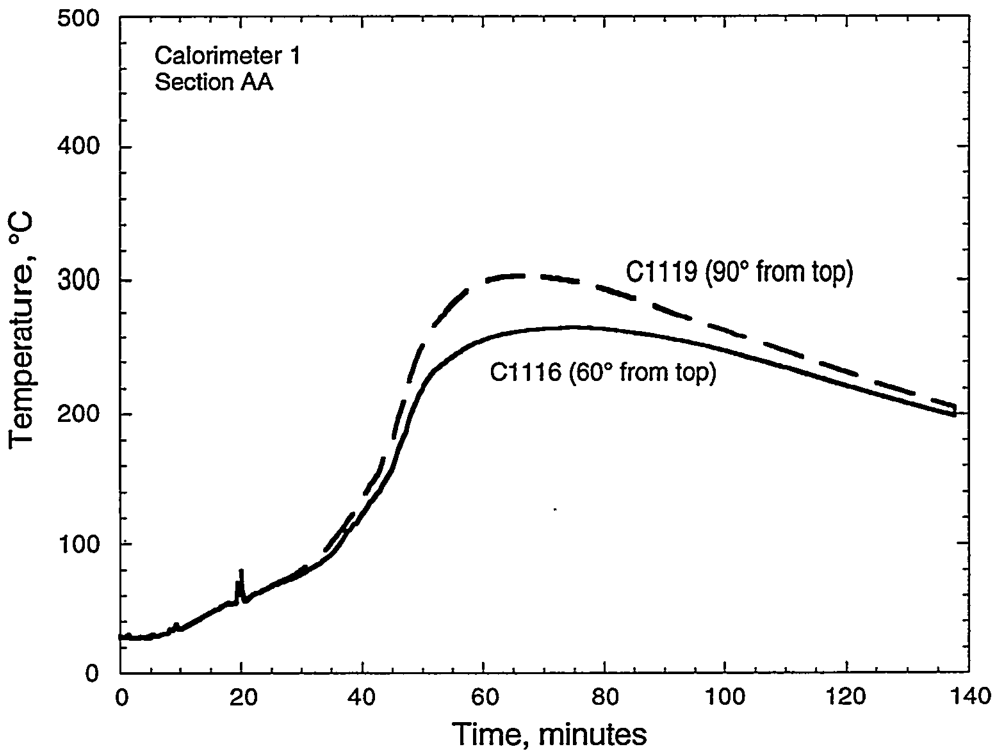


Figure 25. Thermocouple temperatures for Section AA of Calorimeter 1.

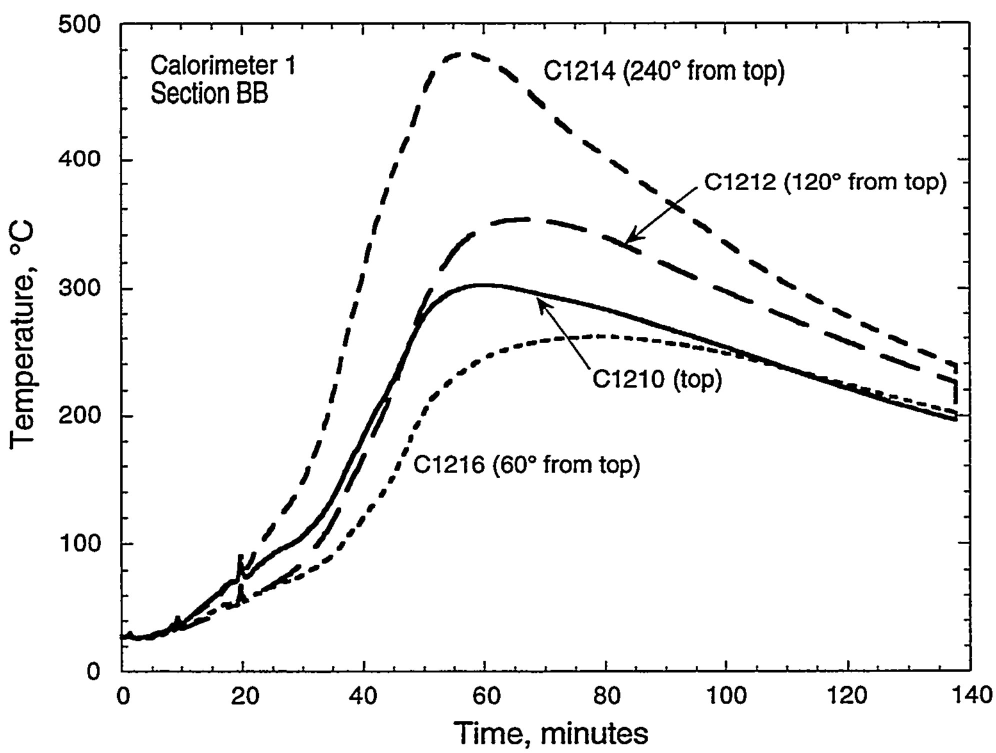


Figure 26. Thermocouple temperatures for Section BB of Calorimeter 1.

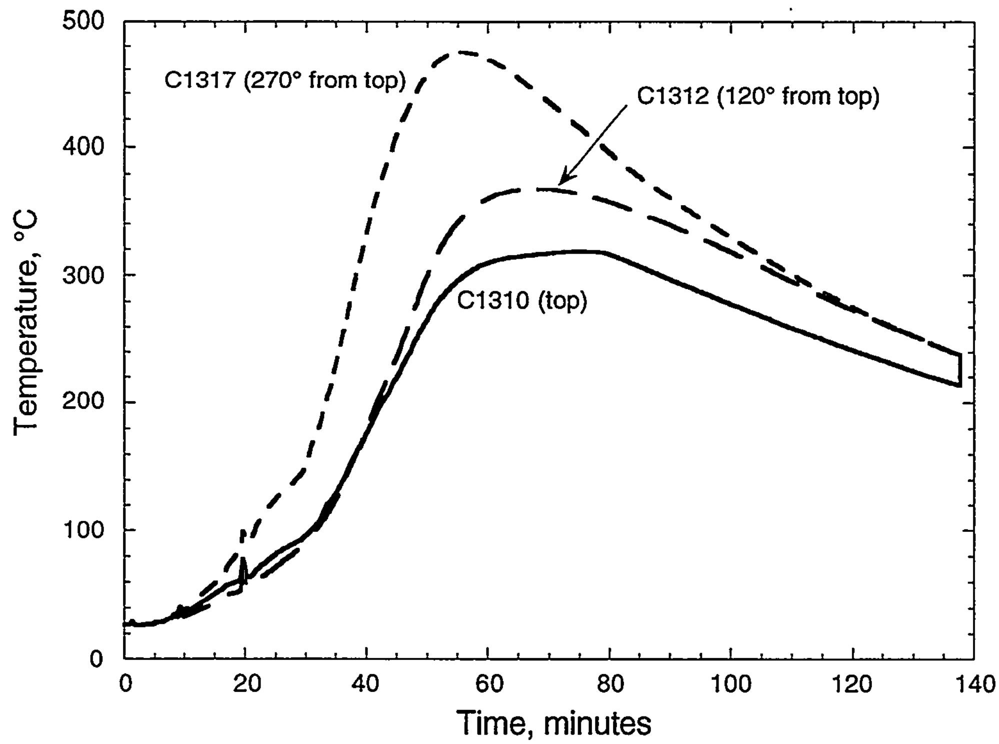


Figure 27. Thermocouple temperatures for section CC of Calorimeter 1.

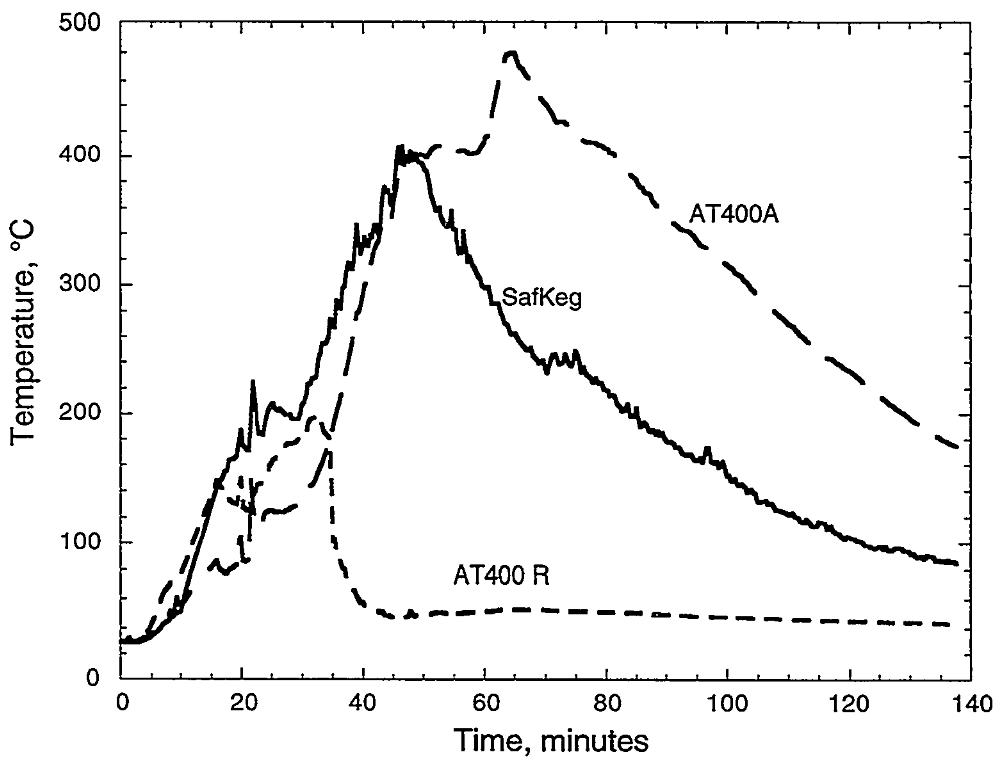


Figure 28. Surface temperature thermocouple response for packages in Container 2.

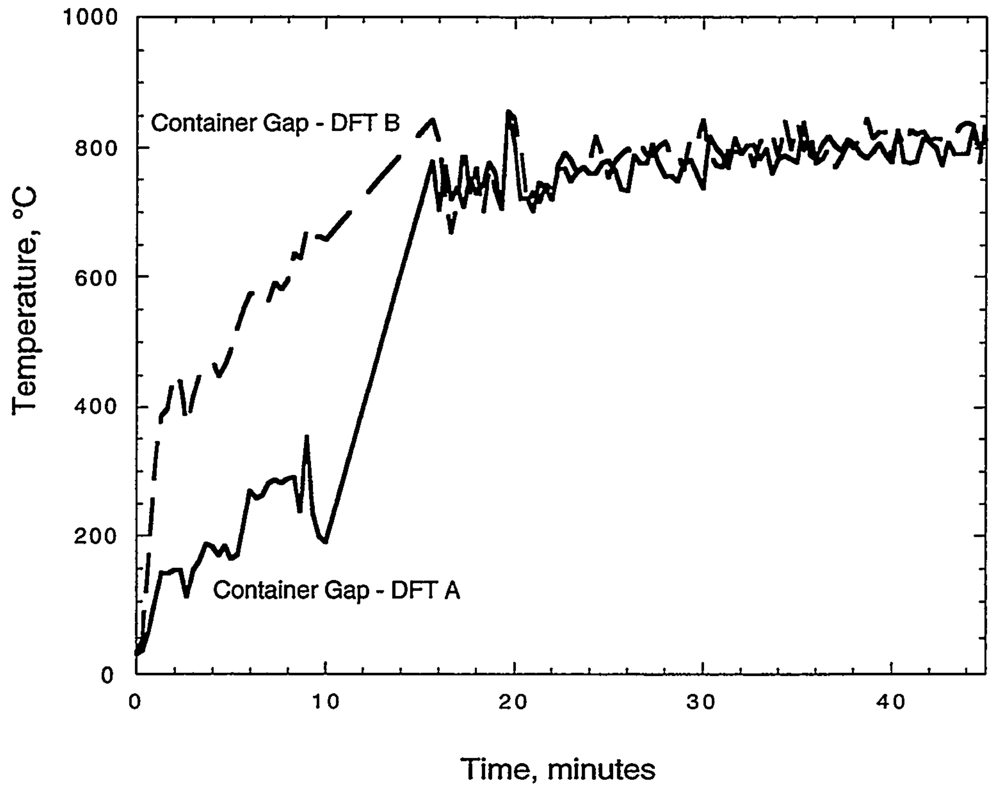


Figure 29. Temperatures for Directional Flame Thermometers in gap between Containers 2 and 5.

121°C, respectively. Post test inspection showed that the intumescent foam in all the AT400A containers reached temperatures where protective swelling of the foam material starts to occur.

3.4 Directional Flame Thermometers

Results for the DFTs mounted in the gap between Containers 2 and 5 are shown in Figure 29. After the stack collapse, these DFTs were located above the side of Container 2 (see Figure 11 for approximate location), but not in the flame zone. Temperatures near 800°C were recorded until about 45 minutes after ignition when the thermocouples ceased to function properly. DFTs originally on the fire side provided only minimal data before the collapse and results are not provided here.

3.5 Weight Measurements

Weighing of the containers after the fire often indicated that weight loss exceeded cargo weight, indicating that the wood floors of the containers had also completely burned. This was confirmed by visual inspection which showed that all floors and cargo had burned to ashes. The weights consumed in the fire are given in Appendix A.

4.0 Conclusions

The test was successful in reproducing the fire environment that could be encountered during the shipment of radioactive materials on a container cargo ship. The burst water line to the support structure that led to the collapse of the container stack reduced the amount of data available regarding radioactive materials packages in a stacked fire environment, but the remaining data were sufficient to produce accurate simulations of such package conditions.

All containers showed high wall temperatures, typically in the 800 to 1000°C range. This is not unexpected for thin sheets of steel placed near an active fire. Simulations of radioactive materials packages should consider that containers with combustible cargoes are capable of reaching such temperatures as are containers directly exposed to an open pool fire. In most cases, the steel walls of the container containing the radioactive materials packages will act as a thermal radiation shield, and will to block the direct thermal radiation from adjacent containers and open pool fires.

An unanticipated finding of the experiment was the role of wood flooring in spread of container fires. Besides providing a source of combustible material, the floors all completely burned, allowing oxygen to enter the containers through the gaps between the steel cross members that support the floor. All simulated cargo materials including paper bales, cardboard box bales, and wood pallets burned almost completely. Only in ISO Container 5 were contents still actively burning 24 hours later, but these contents were close to completely burned. For shipments of radioactive materials, standard wood floors of the ISO containers should be replaced with steel plates to retard fire spread to interior combustible items.

Initially, doubt existed as to whether the contents of ISO containers not located directly over the burning surface of the fire would ignite. The contents not only ignited, but thermocouple traces indicate that most of the contents were burned by the end of the 52 minute pool fire.

Surface temperatures of some radioactive materials packages located in Container 2 reached the 400 to 500°C range despite the collapse of the stack into the pool at 16 minutes. Internal temperatures of one AT400A package (the smallest package in the container) reached 166°C. Most of this exposure was probably due to the wood floor burning under the steel plates placed over the floor of ISO Container 2.

With only a few exceptions, the cooling trends in the thermocouple records indicate that the combustible contents of the ISO containers were completely burned at the end of the pool fire period. This supports the concept that traveling fires are the most likely type to occur on large container ships, where cargo fires would spread from one container to another with each container burning for a relatively short period of time. This also indicates that long burning container ship fires could behave like forest fires, with a burn front moving through the combustibles in a group of the containers. Although such fires could last for long periods of time, locally, the time exposure of a radioactive materials package to fire would depend on the amount of combustible material in surrounding containers. The complete combustion of the simulated cargo is consistent with reports of the *Sea Witch* fire in New York harbor. Coast Guard records [1] indicate that most cargo damage occurred in containers stowed on-deck. The same reports indicated that containers in holds below deck showed much less damage, and did not significantly contribute to the fire.

For the fires studied here, oxygen was readily available to support combustion. Below decks on container ships, the oxygen supply could limit fires to less intense, but longer burning smoldering fires. An experiment to assess the effect of oxygen availability on cargo fires has been designed, and will be the subject of future efforts in this area.

5.0 References

1. *Marine Casualty Report: SS C. V. Sea Witch--SS ESSO Brussels Collision and Fire, New York Harbor, 2 June 1973 with Loss of Life*, US Coast Guard Marine Board of Investigation Report and Commandant's Action; Action by National Transportation Safety Board, USCG/NTSB-MAR-75-6, December 17, 1975.

2. Burgess, M. H., and C. J. Fry. *Fire Testing for Package Approval* **RAMTRANS** vol. 1, no. 1 (1990): 7-16.

APPENDIX A

Container Setup and Experimental Data

Container 1 Thermocouple Locations

ID Number	Device Type	Distance from rear wall x, m	Distance from fire facing (left) wall y, m	Height above floor z, m	Cable Number	Circuit Number	Comments
TC1101	T/C, type K	4.60	0	1.92	1	1	
TC1102	T/C, type K	1.17	0	0.53	2	2	
TC1201	T/C, type K	3.15	2.39	1.14	6	6	
TC1301	T/C, type K	6.05	1.55	1.17	4	4	
TC1401	T/C, type K	0	1.22	1.17	5	5	
TC1501	T/C, type K	0.66	1.13	0	7	7	
TC1601	T/C, type K	2.24	1.26	2.39	3	3	

ID Key
First digit=Container number
Second digit=Container side number (see sketch)
Third and fourth digits=Sequence number

Manufacturer: Deutche Reichsbaum, Type G+6, 1988
S/N 6311-031614, ID No. DSRU832614/9/
Wall thickness = 2.31 mm
Door thickness = 2.81 mm
Roof thickness = 2.77 mm
Fork lift channel thickness = 8.26 mm

Weight Loaded = 3824 kg
Weight Empty = 2495 kg
Contents Weight = 1329 kg
Weight after Fire = 2200 kg
Weight Combusted = 1624 kg

Contents = 4 cardboard box bales

Interior distances measured from the outside of the corrugations in container wall.

Container 2 Thermocouple Locations

ID Number	Device Type	Distance from rear wall x, m	Distance from fire facing (left) wall y, m	Height above floor z, m	Cable Number	Circuit Number	Comments
TC2101	T/C, type K	4.57	0	1.92	8	8	
TC2102	T/C, type K	1.17	0	0.53	9	9	
TC2201	T/C, type K	3.2	2.41	1.14	10	10	
TC2301	T/C, type K	5.99	0.14	3.79	11	11	
TC2401	T/C, type K	0	1.32	1.17	12	12	
TC2501	T/C, type K	3.05	1.05	0	13	13	
TC2601	T/C, type K	2.92	1.32	2.41	14	14	

ID Key
First digit=Container number
Second digit=Container side number (see sketch)
Third and fourth digits=Sequence number

Manufacturer: Transamerica ICS, Type HD-ICC-1100 12
S/N HDI-80-209974, ID No. ICSU 388 348 9
Wall thickness = 2.74 mm
Door thickness = 2.79 mm
Roof thickness = 2.72 mm
Installed steel floor plates over wood deck = 2.41 mm (fire side half), 3.18 mm (non fire side)

T/C PFT 1 = 0.68 m from fire side
T/C 400R Cable No. 15
T/C KEG Cable No. 16
T/C 400A Cable No. 17
T/C DFTFSA Cable No. 18
T/C DFTFSB Cable No. 19
T/C DFTCSA Cable No. 20
T/C DFTCSB Cable No. 21
Empty weight = 2300 kg

Container 3 Thermocouple Locations

ID Number	Device Type	Distance from rear wall x, m	Distance from fire facing (left) wall y, m	Height above floor z, m	Cable Number	Circuit Number	Comments
TC3101	T/C, type K	4.57	0	1.91	34	34	
TC3102	T/C, type K	1.17	0	0.48	35	35	
TC3201	T/C, type K	3.2	2.41	1.14	36	36	
TC3301	T/C, type K	6.05	1.32	1.14	37	37	
TC3401	T/C, type K	0	1.33	1.14	38	38	
TC3501	T/C, type K	3.05	1.22	0	39	39	
TC3601	T/C, type K	3.12	1.22	2.41	40	40	

ID Key
First digit=Container number
Second digit=Container side number (see sketch)
Third and fourth digits=Sequence number

Manufacturer: Transamerica, Mfg. 11/80
ID# 398722 5
Wall thickness = 2.11 mm
Door thickness = 2.51 mm
Roof thickness = 2.54 mm
Thickness of lengthwise steel floor strips = 3.68 mm

Weight Loaded = 5101 kg
Weight Empty = 2489 kg
Contents Weight = 2612 kg
Weight after fire = 5561 kg (water logged)

Contents: 3 bales white paper, pipe calorimeter

Container 4 Thermocouple Locations

ID Number	Device Type	Distance from rear wall x, m	Distance from fire facing (left) wall y, m	Height above floor z, m	Cable Number	Circuit Number	Comments
TC4101	T/C, type K	4.47	0	1.91	53	53	
TC4102	T/C, type K	1.04	0	0.48	54	54	
TC4201	T/C, type K	3.02	2.39	1.14	55	55	
TC4301	T/C, type K	5.99	1.40	1.14	56	56	
TC4401	T/C, type K	0	1.30	1.14	57	57	
TC4501	T/C, type K	2.85	1.63	1.52	58	58	Stapled to wood pallet
TC4601	T/C, type K	3.05	1.22	2.39	59	59	

ID Key
First digit=Container number
Second digit=Container side number (see sketch)
Third and fourth digits=Sequence number

Manufacturer: Trailor 5/80
S/N 982, ID No. ICSU 3740088/7/
Wall thickness = 3.00 mm
Door thickness = 2.69 mm
Roof thickness = 3.56 mm

Weight Loaded = 3182 kg
Weight Empty = 2170 kg
Contents Weight = 1012 kg
Weight after fire = 1783 kg
Weight Combusted = 1399 kg

Contents = scrap wood pallets

Sheet metal patch applied to fire side wall, low (to cover a hole)

Container 5 Thermocouple Locations

ID Number	Device Type	Distance from rear wall x, m	Distance from fire facing (left) wall y, m	Height above floor z, m	Cable Number	Circuit Number	Comments
TC5101	T/C, type K	4.60	0	1.91	60	60	
TC5102	T/C, type K	1.14	0	0.48	61	61	
TC5201	T/C, type K	3.22	2.39	1.14	62	62	
TC5301	T/C, type K	6.05	1.37	1.14	63	63	
TC5401	T/C, type K	0	1.32	1.14	64	64	
TC5501	T/C, type K	3.05	1.35	4.88	65	65	
TC5601	T/C, type K	3.15	1.22	7.92	66	66	

ID Key
First digit=Container number
Second digit=Container side number (see sketch)
Third and fourth digits=Sequence number

Manufacturer: Transamerica, 7/81
ID No. HDI-812177945
Wall thickness = 2.41 mm
Door thickness = 3.10 mm
Roof thickness = 3.18 mm

Weight Loaded = 4750 kg
Weight Empty = 2418 kg
Contents Weight = 2332 kg
Weight Combusted = approx. 1500 kg (still smoldering after 24 hours, weight not possible, approx. 1.5 bales left)

Container 6 Thermocouple Locations

ID Number	Device Type	Distance from rear wall x, m	Distance from fire facing (left) wall y, m	Height above floor z, m	Cable Number	Circuit Number	Comments
TC6101	T/C, type K	4.60	0	1.91	82	82	
TC6102	T/C, type K	1.14	0	1.58	83	83	
TC6201	T/C, type K	3.30	2.41	1.14	84	84	
TC6301	T/C, type K	5.99	1.33	1.14	85	85	
TC6401	T/C, type K	0	1.32	1.14	86	86	
TC6501	T/C, type K	3.05	1.22	0	87	87	
TC6601	T/C, type K	3.18	1.22	2.41	88	88	

ID Key
First digit=Container number
Second digit=Container side number (see sketch)
Third and fourth digits=Sequence number

Manufacturer: Transamerica, 10/80
ID No. 396841
Wall thickness = 2.18

Weight Loaded = 3395 kg
Weight Empty = 2720 kg
Contents Weight = 675 kg

Contents: Calorimeter 3 (stainless steel)

Container 7 Thermocouple Locations

ID Number	Device Type	Distance from rear wall x, m	Distance from fire facing (left) wall y, m	Height above floor z, m	Cable Number	Circuit Number	Comments
TC7101	T/C, type K	5.57	0	1.91	89	89	
TC7102	T/C, type K	1.40	0	0.48	90	90	
TC7201	T/C, type K	2.97	2.40	1.14	91	91	
TC7301	T/C, type K	5.97	1.35	1.14	92	92	
TC7401	T/C, type K	0	1.35	1.14	93	93	
TC7501	T/C, type K	3.05	1.22	0	94	94	
TC7601	T/C, type K	2.90	1.22	2.39	95	95	

ID Key
First digit=Container number
Second digit=Container side number (see sketch)
Third and fourth digits=Sequence number

Manufacturer: Fuji Heavy Industries, 4/81, Type 26SD-C04-T08
ID No. ICSU405073 8
Wall thickness = 2.92 mm
Door thickness = 2.54 mm (plate), 3.81 mm (channels)
Roof thickness = 2.54 mm
Corner channel thickness (by doors) = 6.02 mm

Weight Loaded = 2890 kg
Weight Empty = 2316 kg
Contents Weight = 574 kg
Weight after Fire = 2009 kg
Weight Combusted = 881 kg

Contents: 1 bale white paper near fire facing wall

Container 8 Thermocouple Locations

ID Number	Device Type	Distance from rear wall x, m	Distance from fire facing (left) wall y, m	Height above floor z, m	Cable Number	Circuit Number	Comments
TC8101	T/C, type K	4.55	0	1.91	96	96	
TC8102	T/C, type K	1.19	0	0.48	97	97	
TC8201	T/C, type K	3.16	2.40	1.14	98	98	
TC8301	T/C, type K	5.99	1.35	1.14	99	99	
TC8401	T/C, type K	0	1.31	1.14	100	100	
TC8501	T/C, type K	3.05	1.22	0	101	101	
TC8601	T/C, type K	3.10	1.22	2.41	102	102	

ID Key
First digit=Container number
Second digit=Container side number (see sketch)
Third and fourth digits=Sequence number

Manufacturer: Not identified
ID No. Y-153
Wall thickness = 3.15 mm
Door thickness = 2.59 mm
Roof thickness = 2.67 mm

Weight Loaded = 2852 kg
Weight Empty = 2219 kg
Contents Weight = 633 kg
Weight after Fire = 1896 kg
Weight Combusted = 686 kg

Contents: 1 bale white paper near fire facing wall

Container 9 Thermocouple Locations

ID Number	Device Type	Distance from rear wall x, m	Distance from fire facing (left) wall y, m	Height above floor z, m	Cable Number	Circuit Number	Comments
TC9101	T/C, type K	4.60	0	1.91	103	103	
TC9102	T/C, type K	1.19	0	0.48	104	104	
TC9201	T/C, type K	3.23	2.39	1.14	105	105	
TC9301	T/C, type K	5.98	1.35	1.14	106	106	
TC9401	T/C, type K	0	1.32	1.14	107	107	
TC9501	T/C, type K	3.05	1.22	0	108	108	
TC9601	T/C, type K	3.12	1.21	2.39	109	109	

ID Key
First digit=Container number
Second digit=Container side number (see sketch)
Third and fourth digits=Sequence number

Manufacturer: Transamerica
S/N C8007666, ID No. ICSU397388 0
Wall thickness = 2.24 mm
Door thickness = 2.69 mm
Roof thickness = 2.67 mm
Floor rain thickness = 2.59 mm

Weight Loaded = 2827 kg
Weight Empty = 2216 kg
Contents Weight = 611 kg
Weight after Fire = 1923 kg
Weight Combusted = 904 kg

Contents: 1 bale white paper near fire facing wall

Calorimeter 1 Instrumentation Locations

ID Number	Device Type	Location	Angle from top, degrees	Cable Number	Channel Number
TC1116	T/C Type K	Section AA inside	60	22	22
TC1119	T/C Type K	Section AA inside	90	23	23
TC1118	T/C Type K	Section AA inside	180	24	24
TC1210	T/C Type K	Section BB inside	0	25	25
TC1216	T/C Type K	Section BB inside	60	26	26
TC1212	T/C Type K	Section BB inside	120	27	27
TC1214	T/C Type K	Section BB inside	240	28	28
TC1310	T/C Type K	Section CC inside	0	29	29
TC1312	T/C Type K	Section CC inside	120	30	30
TC1317	T/C Type K	Section CC inside	270	31	31
TC1410	T/C Type K	End AA inside centered	n/a	32	32
TC1510	T/C Type K	End CC inside 150 mm from rim	90	33	33

ID Key
First digit = Calorimeter number
Second digit=1 for AA, 2 for BB, 3 for CC, 4 for end AA, 5 for end CC
Third digit=1 for inside, 2 for outside
Fourth digit=0 for top, 6 for 60°, 9 for 90°, 2 for 120°,4 for 240°, 7 for 270°

Calorimeter 2 Instrumentation Locations

ID Number	Device Type	Location	Angle from top, degrees	Cable Number	Channel Number
TC2116	T/C Type K	Section AA inside	60	41	41
TC2119	T/C Type K	Section AA inside	90	42	42
TC2118	T/C Type K	Section AA inside	180	43	43
TC2210	T/C Type K	Section BB inside	0	44	44
TC2216	T/C Type K	Section BB inside	60	45	45
TC2212	T/C Type K	Section BB inside	120	46	46
TC2214	T/C Type K	Section BB inside	240	47	47
TC2310	T/C Type K	Section CC inside	0	48	48
TC2312	T/C Type K	Section CC inside	120	49	49
TC2317	T/C Type K	Section CC inside	270	50	50
TC2410	T/C Type K	End AA inside centered	n/a	51	51
TC2510	T/C Type K	End CC inside 150 mm from rim	90	52	52

ID Key
First digit = Calorimeter number
Second digit=1 for AA, 2 for BB, 3 for CC, 4 for end AA, 5 for end CC
Third digit=1 for inside, 2 for outside
Fourth digit=0 for top, 6 for 60°, 9 for 90°, 2 for 120°,4 for 240°, 7 for 270°

Calorimeter 3 Instrumentation Locations

ID Number	Device Type	Location	Angle from top, degrees	Cable Number	Channel Number
TC3119	T/C Type K	Section AA inside	90	67	67
TC3118	T/C Type K	Section AA inside	180	68	68
TC3113	T/C Type K	Section AA inside	300	69	69
TC3210	T/C Type K	Section BB inside	0	70	70
TC3216	T/C Type K	Section BB inside	60	71	71
TC3212	T/C Type K	Section BB inside	120	72	72
TC3222	T/C Type K	Section BB outside	120	73	73
TC3218	T/C Type K	Section BB inside	180	74	74
TC3214	T/C Type K	Section BB inside	240	75	75
TC3213	T/C Type K	Section BB inside	300	76	76
TC3310	T/C Type K	Section CC inside	0	77	77
TC3312	T/C Type K	Section CC inside	120	78	78
TC3317	T/C Type K	Section CC inside	270	79	79
TC3410	T/C Type K	End AA inside centered	n/a	80	80
TC3510	T/C Type K	End CC inside 150 mm from rim	90	81	81

ID Key
First digit = Calorimeter number
Second digit=1 for AA, 2 for BB, 3 for CC, 4 for end AA, 5 for end CC
Third digit=1 for inside, 2 for outside
Fourth digit=0 for top, 6 for 60°, 9 for 90°, 2 for 120°,4 for 240°, 7 for 270°,3 for 300°

APPENDIX B

Additional Container Thermocouple Plots

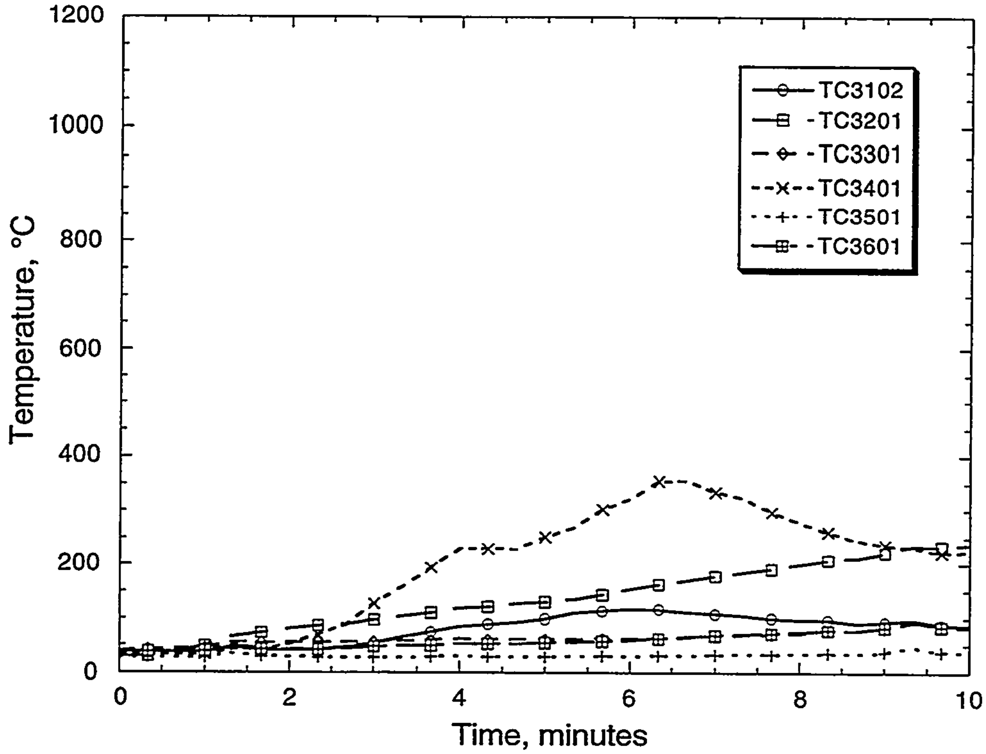


Figure B-1. Pre-collapse temperatures from Container 3

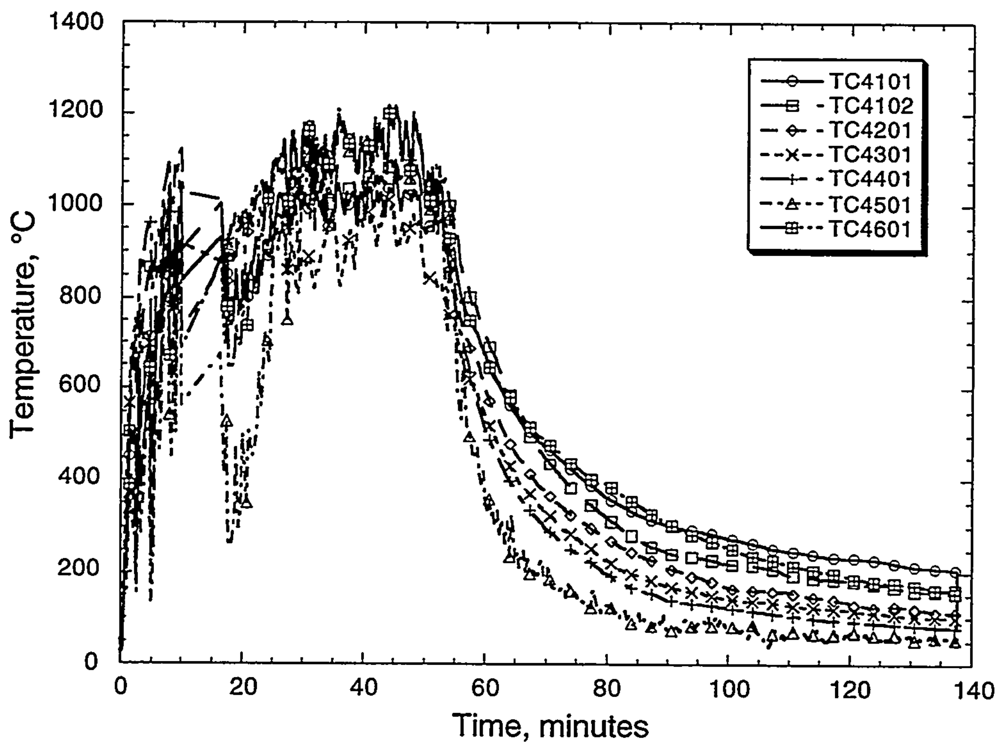


Figure B-2. Container 4 results for period during and following pool fire.

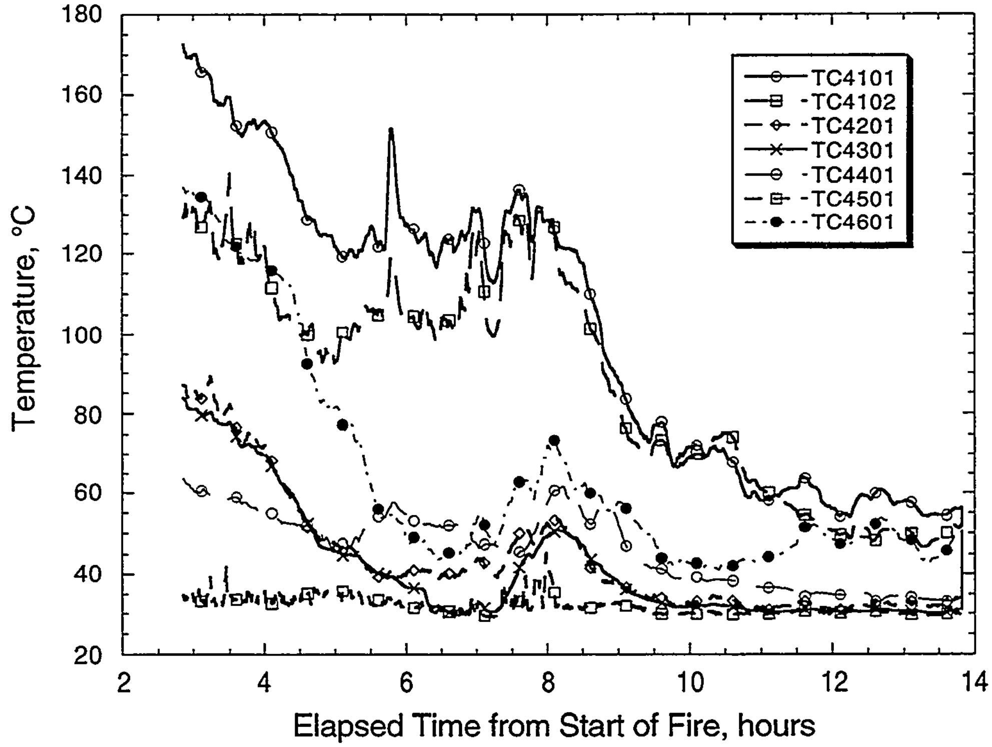


Figure B-3. Container 4 temperatures between 2 and 14 hours after ignition

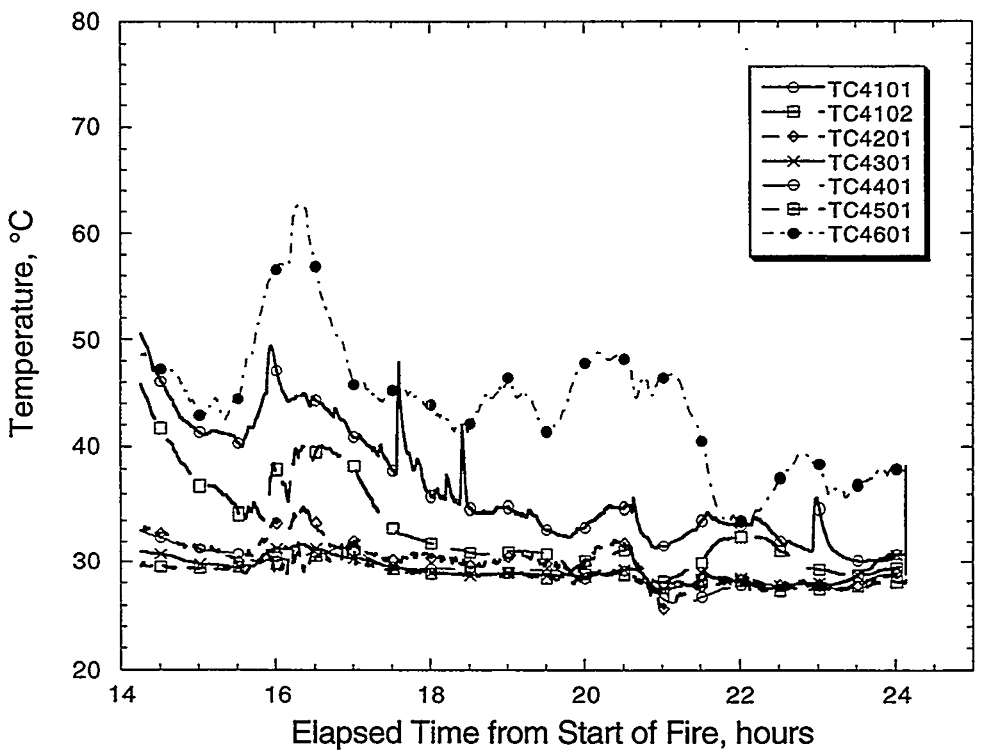


Figure B-4. Container 4 temperatures during night after pool fire.

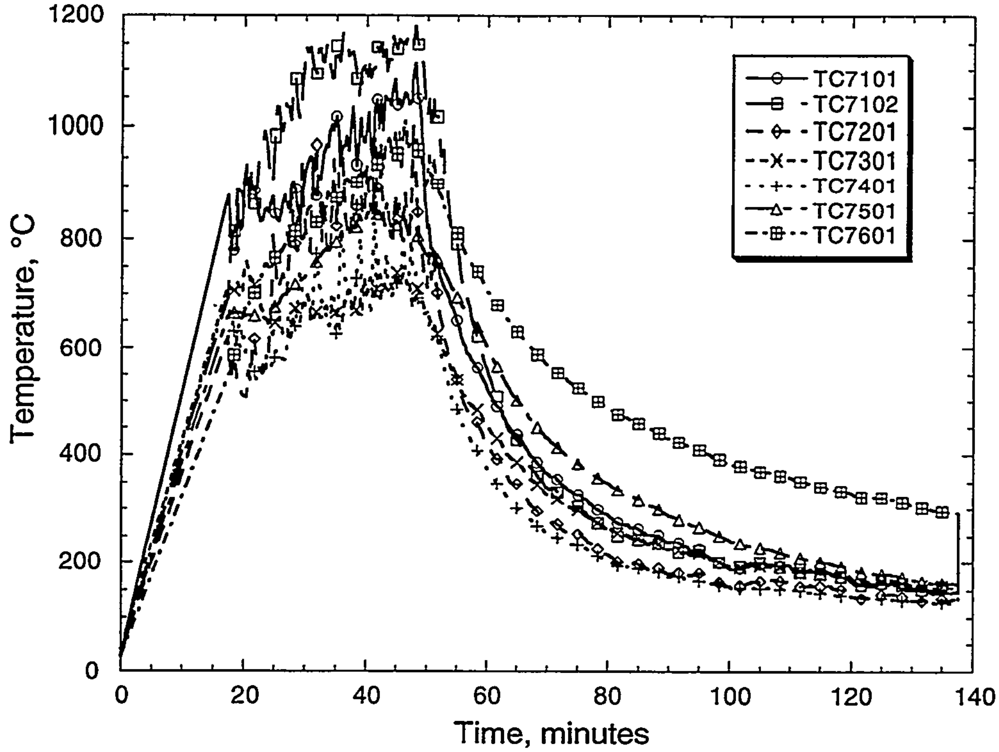


Figure B-5. Container 7 thermocouple results for period during and following pool fire.

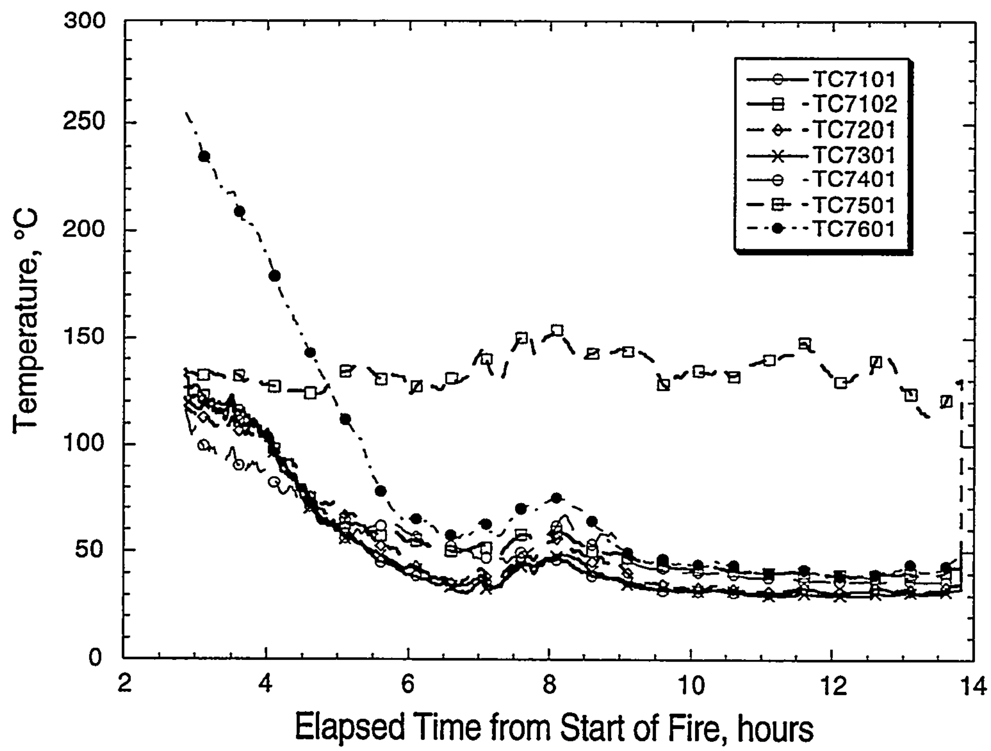


Figure B-6. Container 7 temperatures between 2 and 14 hours after ignition.

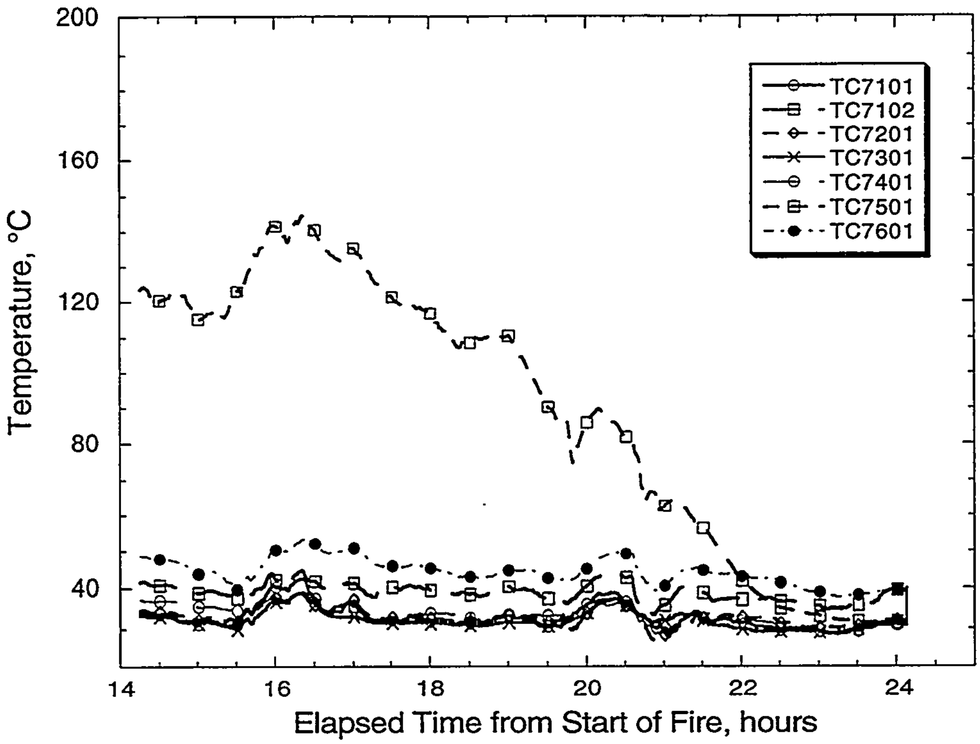


Figure B-7. Container 7 temperatures during night after pool fire.

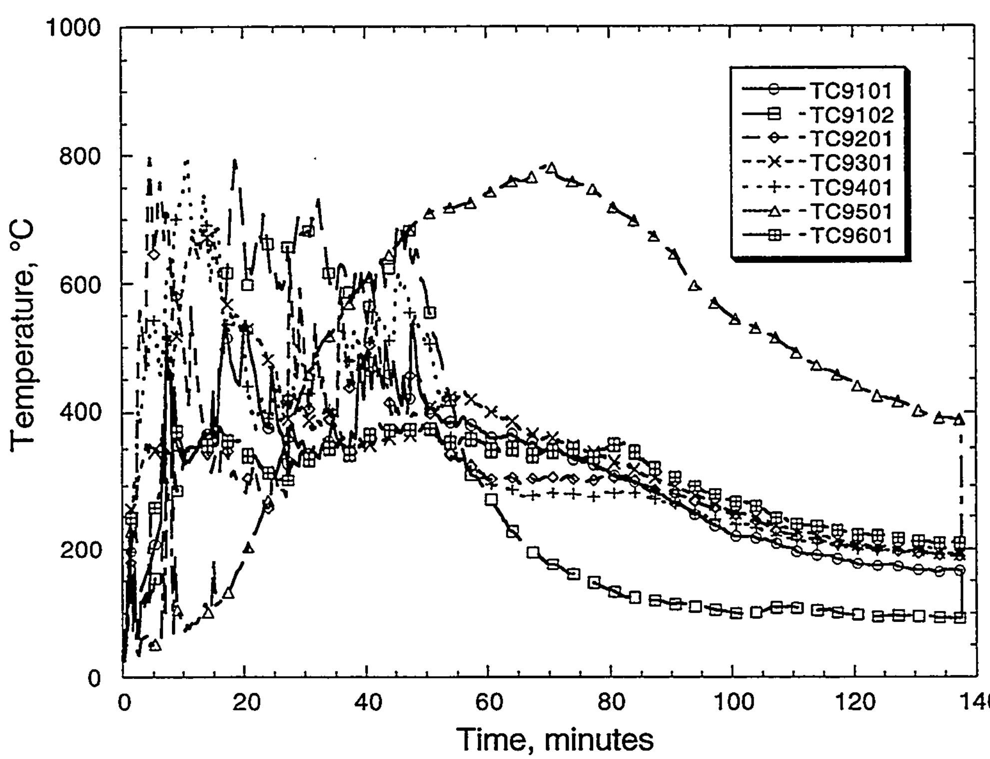


Figure B-8. Container 9 thermocouple results for period during and following pool fire.

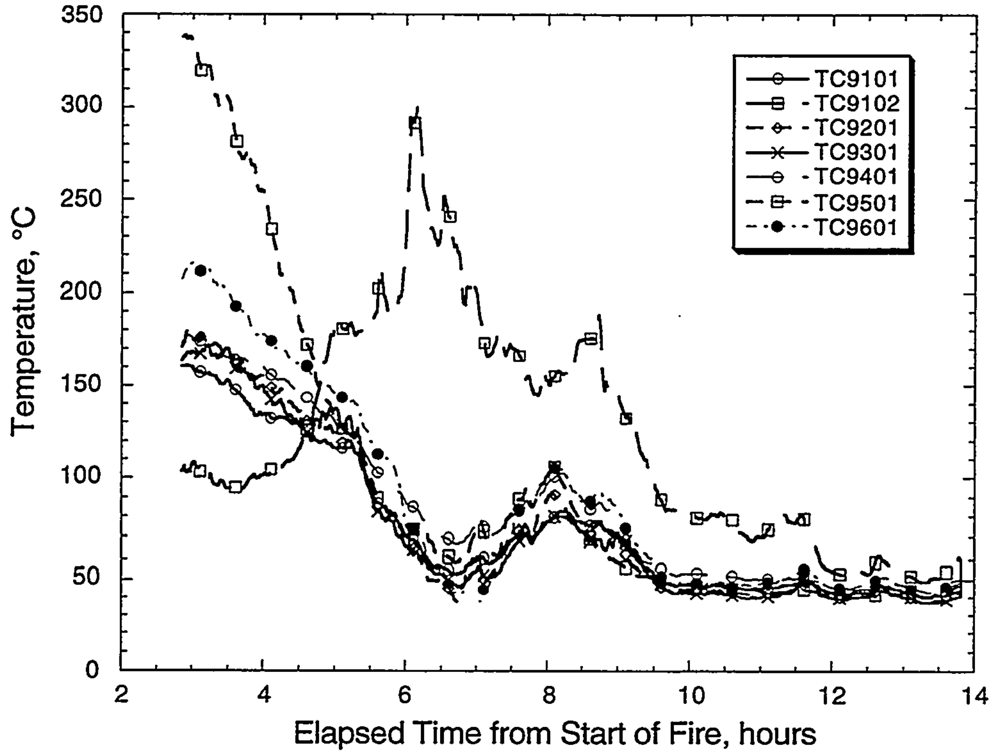


Figure B-9. Container 9 temperatures between 2 and 14 hours after ignition.

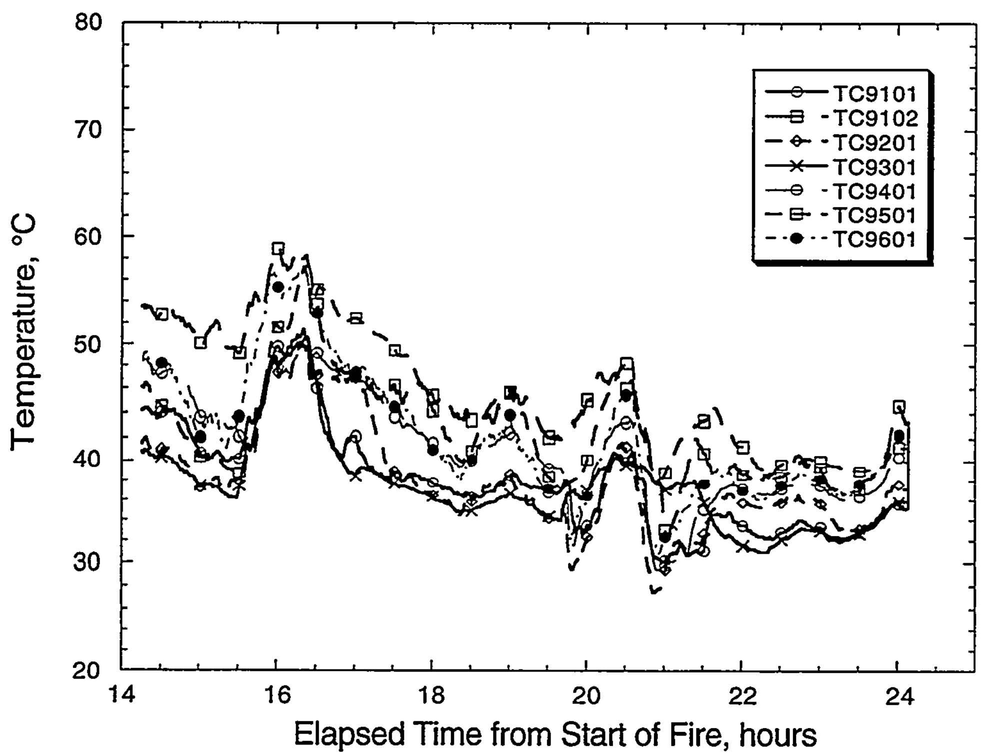


Figure B-10. Container 9 temperatures during night after pool fire.

APPENDIX C

Package Temperature Strip Results

Temperature Label Form

Container Type **AT400A**

Container I.D.# **AT400A2**

Label Set 1 Location Exterior - fire side Temperature Range 100 - 600 °F

Peak Temperature Read 230 °F Date 8.28

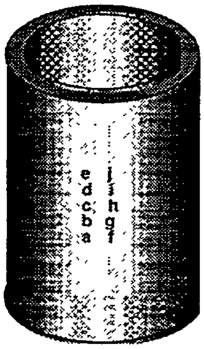
Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 330 °F

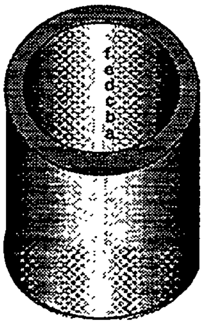
Peak Temperature Read 110 °F Date 8/28

Tempilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear





Fire side toward front

Comments: 2/3 immersed in water after 15 minutes. Four of ten expansion plugs left.

Temperature Label Form

Container Type AT400A ___

Container I.D.# AT400A1 __

Label Set 1 Location Exterior - fire side _______ Temperature Range 100 - 600 °F ______

Peak Temperature Read 330 °F _____ Date 8/28 ___

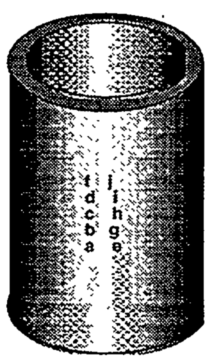
Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 330 °F _____

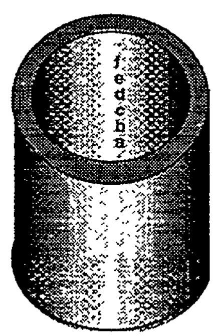
Peak Temperature Read 170 °F _____ Date 8/28 ____

Tempilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear





Fire side toward front

Comments: Four of 10 plugs remaining. 1/4 immersed in water after 15 minutes.

Temperature Label Form

Container Type AT400A ___

Container I.D.# AT400A3 _

Label Set 1 Location Exterior - fire side _______ Temperature Range 100 - 600 °F______

Peak Temperature Read 650 °F _____ Date 8/28 ___

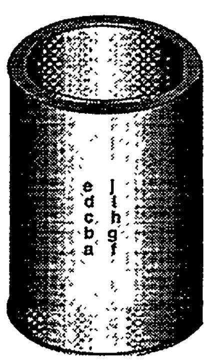
Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 330 °F _____

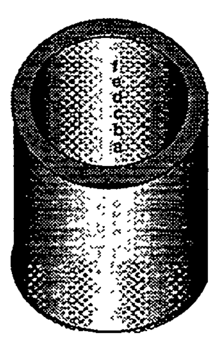
Peak Temperature Read 330 °F _____ Date 8/28 ____

Tempilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear





Fire side toward front

Comments: 10% immersed in water after 15 minutes. All but 1 plug gone.

Temperature Label Form

Container Type AT400A

Container I.D.# AT400A4

Label Set 1 Location Exterior - fire side Temperature Range 100 - 600 °F

Peak Temperature Read 600 °F Date 8/28

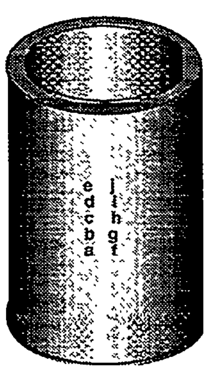
Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 330 °F

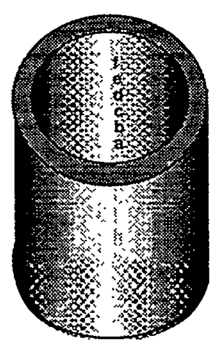
Peak Temperature Read 250 °F Date 8/28

Tempilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear





Fire side toward front

Comments: 1/4 immersed in water after 15 minutes.

Temperature Label Form

Container Type **AT400R** ___

Container I.D.# **AT400R1** ___

Label Set 1 Location Exterior - fire side _______ Temperature Range 100 - 600 °F _______

Peak Temperature Read 330 °F _____ Date _______ Time ________ By ______________

Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 250 °F _____

Peak Temperature Read 130 °F _____ Date _______ Time ________ By ______________

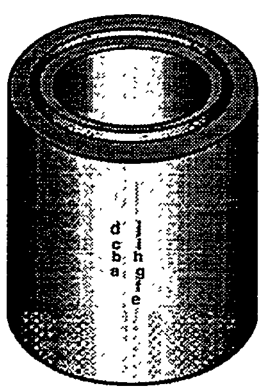
Label Set 3 Location Interior second wall - fire side Temperature Range 100 - 210 °F ___

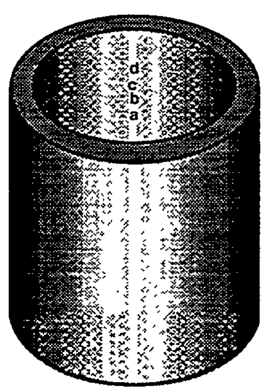
Peak Temperature Read ≤100 °F ____ Date _______ Time ________ By ______________

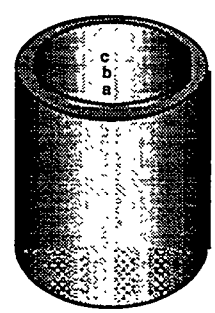
Tempilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear







Fire side toward front

Comments: Immersed after 15 minutes.

Temperature Label Form

Container Type AT400R

Container I.D.# AT400R2

Label Set 1 Location Exterior - fire side Temperature Range 100 - 600 °F

Peak Temperature Read ≤340 °F Date 8/28

Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 250 °F

Peak Temperature Read 130 °F Date 8/28

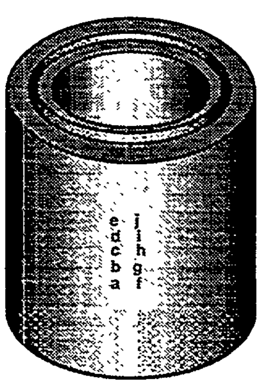
Label Set 3 Location Interior second wall - fire side Temperature Range 100 - 250 °F

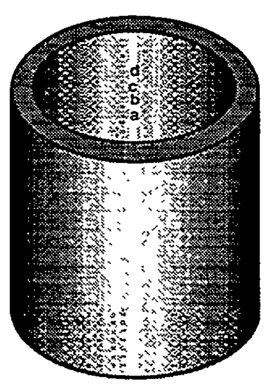
Peak Temperature Read ≤100 °F Date 8/28

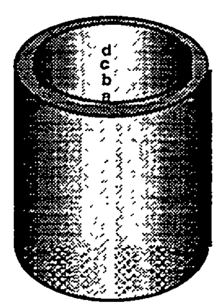
Templilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear







Fire side toward front

Comments: Immersed after 15 minutes.

Temperature Label Form

Container Type AT400R

Container I.D.# AT400R3

Label Set 1 Location Exterior - fire side Temperature Range 100 - 600 °F

Peak Temperature Read unknown Date 8/28 Time________ By ______________

Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 250 °F

Peak Temperature Read ≤100 °F Date 8/28 Time________ By ______________

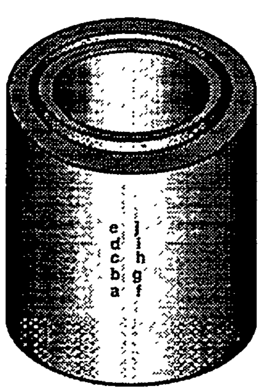
Label Set 3 Location Interior second wall - fire side Temperature Range 100 - 250 °F

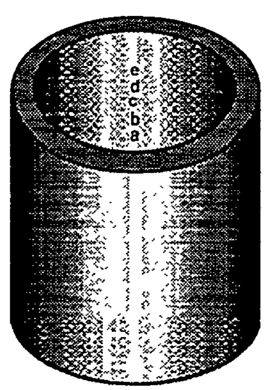
Peak Temperature Read N/A Date________ Time________ By ______________

Tempilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear





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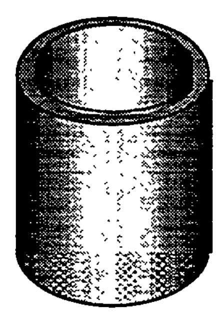


Fire side toward front

Comments: Immersed after 15 minutes.

Temperature Label Form

Container Type AT400R-D

Container I.D.# AT400R4

Label Set 1 Location Exterior - fire side Temperature Range 100 - 600 °F

Peak Temperature Read 290 °F Date ______ Time ______ By ______

Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 290 °F

Peak Temperature Read 130 °F Date ______ Time ______ By ______

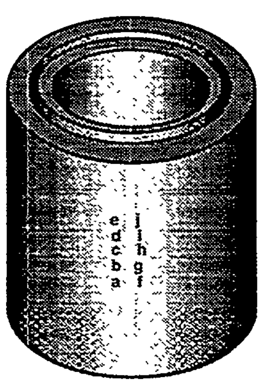
Label Set 3 Location Interior second wall - fire side Temperature Range N/A

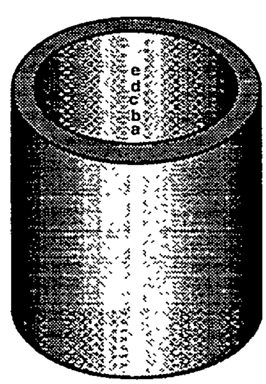
Peak Temperature Read N/A Date ______ Time ______ By ______

Templilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear





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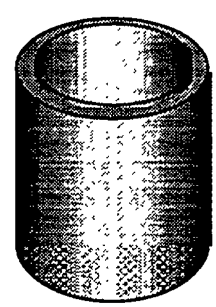


Fire side toward front

Comments: Immersed after 15 minutes.

Temperature Label Form

Container Type RFD

Container I.D.# RFD1

Label Set 1 Location Exterior - fire side Temperature Range 100 - 600 °F

Peak Temperature Read Obscured Date 8/28 Time By

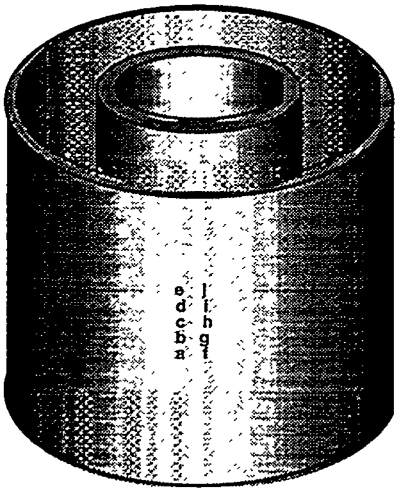
Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 370 °F

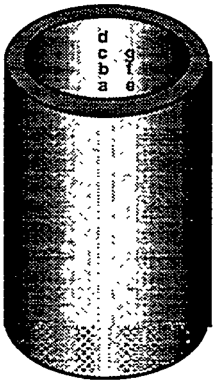
Peak Temperature Read 130 °F Date 8/28 Time By

Tempilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear





Fire side toward front

Temperature Label Form

Container Type RFD

Container I.D.# RFD2

Label Set 1 Location Exterior - fire side Temperature Range 100 - 600 °F

Peak Temperature Read <370 °F Date 8/28

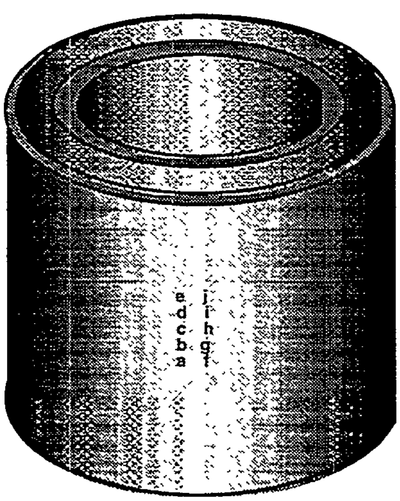
Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 370 °F

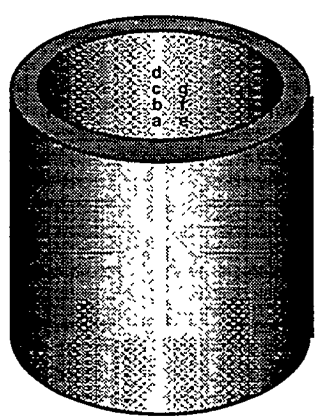
Peak Temperature Read 140 °F Date 8/28

Templilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear





Fire side toward front

Temperature Label Form

Container Type RFD

Container I.D.# RFD3

Label Set 1 Location Exterior - fire side Temperature Range 100 - 600 °F

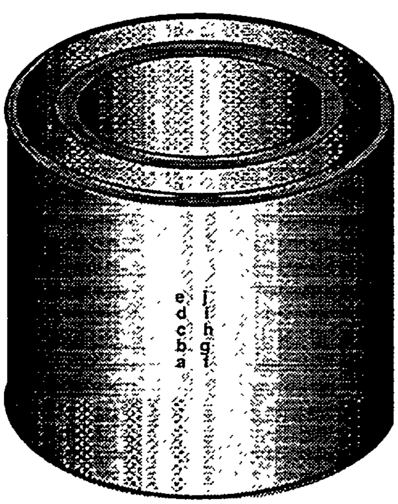
Peak Temperature Read >500 °F Date 8/28

Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 370 °F

Peak Temperature Read 150 °F Date 8/28

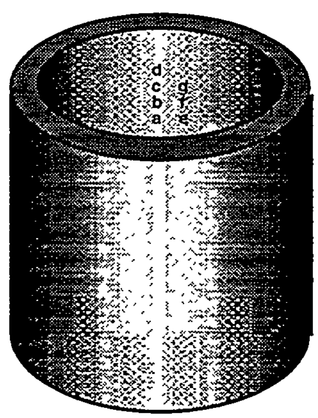
Tempilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:



Fire side toward front

Fire Side toward rear



Temperature Label Form

Container Type RFD

Container I.D.# RFD4

Label Set 1 Location Exterior - fire side Temperature Range 100 - 600 °F

Peak Temperature Read <370 °F Date 8/28

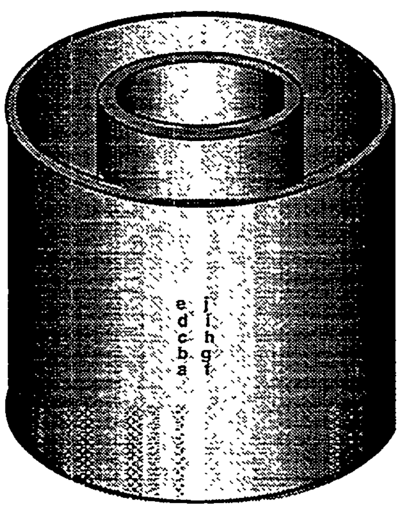
Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 370 °F

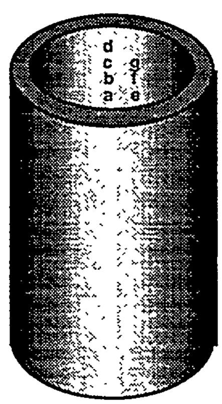
Peak Temperature Read 140 °F Date 8/28

Templilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear





Fire side toward front

Temperature Label Form

Container Type Safe Keg __

Container I.D.# **SK1** ______

Label Set 1 Location Exterior - fire side _______ Temperature Range 100 - 600 °F______

Peak Temperature Read 250 °F _____ Date 8/28 ___

Label Set 2 Location Interior first wall - fire side Temperature Range 100 - 600 °F ______

Peak Temperature Read 120-130 °F __ Date 8/28 ___

Label Set 3 Location Interior second wall - fire side Temperature Range 100 - 250 °F___

Peak Temperature Read <82 °F _____ Date 8/28 ___

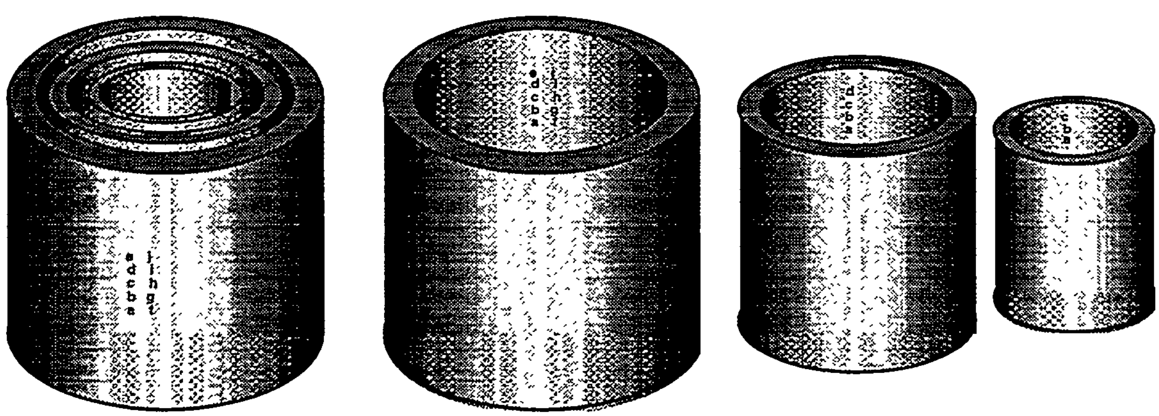
Label Set 4 Location Interior third wall - fire side Temperature Range 100 - 210 °F_____

Peak Temperature Read <82 °F _____ Date 8/28 ___

Tempilables	a	b	c	d	e	f	g	h	I	j
Temperature Range	100 - 130 °F	140 - 170 °F	180 - 210 °F	220 - 250 °F	260 - 290 °F	300 - 330 °F	340 - 370 °F	370 - 400 °F	425 - 500 °F	450 - 600 °F
Temperature Increment	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	10 °F	25 °F	50 °F

Sketch/Photo:

Fire Side toward rear



Fire side toward front

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