Alternative Thermal Test of a Transport Package in a Laboratory Facility

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ABSTRACT:

This paper describes an oil-fired burner test apparatus at General Plastics Manufacturing Company in Tacoma, Washington and the results of tests to demonstrate alternative testing compliance with IAEA thermal tests requirements. The paper discusses the parameters influencing the thermal conditions for type B-packages. An alternative test method for simulating a pool fire environment using an oil burner, 55-gallon drum, and exhaust hood is verified to be suitable for smaller packages. This alternative was developed as a low cost test conducted in a controlled laboratory environment, and to mitigate air pollution due to sooting smoke from large pool fires. During the fire trial, the fire temperatures were measured carefully to determine a true average fire temperature.

A series of tests were conducted. One fire test was performed to develop and verify the thermal parameters to demonstrate compliance to IAEA thermal test requirements, paragraph 728. Another fire test of a typical package was done to validate the testing method. The testing method provides adequate combustion air to support any combustion of package materials, which is a weakness of furnace tests.

An MDS Nordion transport package for the transport of medical isotopes designed in Ottawa, Ontario was tested using this laboratory method. Test parameters and results are discussed. The advantage of using laboratory type testing is that more test cycles are possible resulting in an optimized design.

INTRODUCTION:

Two MDS Nordion F-458 packages were subjected to an enclosed fuel/air hydrocarbon fire environment in accordance with IAEA requirements for the safe transport of radioactive materials. The testing method provides adequate combustion air to support any combustion of package materials, as demonstrated by the observation of smoke and stack gasses, which showed evidence of burning as they exit the stack (as opposed to burning only after mixing with outside air). The maximum diameter of test article that can be effectively evaluated in this apparatus would be 43 cm (17 inches); thus permitting adequate flow around the test article in the confined space of the test drum "furnace."

METHODOLOGY:

The test "furnace" consists of a stainless steel 55 gallon drum (with lid attached) mounted horizontally as shown in Figure 1. Inside drum measurements are 66 cm (22 inches) diameter x 83.8 cm (33 inches) long. The furnace is pierced with two openings, (1) a 30.5 cm x 15.2 cm (12 x 6 inch) oval shaped opening in the lower centerline of the lid for the burner and (2) a 15.2 cm (6 inch) diameter opening with a 25.4 cm (10 inch) tall stainless steel chimney welded in place on the far top end of the drum. The drum is insulated on its outside surfaces with an inorganic mineral felt blanket. Three, horizontal angle iron rails approximately 7.6 cm (3 inches) from the drum's inner surface support the test article, with the central rail taking the test article load and the flanking rails provide centering support.

FIGURE 1: Test Apparatus Configuration

The flame and heat source for these tests was a Park Model DPL 3400 oil burner as described in US Federal Aviation Regulation FAR 25.853, Appendix F Part II, and also in "Powerplant Engineering Report No 3A" (FAA) and DOT/FAA/RD/76/213 "Reevaluation of Burner Characteristics for Fire Resistance Tests" dtd. 1977. Fuel for the tests was number-2 diesel (number-2 heating oil). Fuel and air delivery rates into the burner are adjustable.

The whole apparatus, including the burner, is placed under an exhaust hood to remove pyrolysis gasses generated during testing.

Burner runs were made at 121 and 155 PSIG fuel pressures, which delivered fuel (as determined by weight consumed) at the rates of 0.2474 and 0.2950 lbs/min respectively. This works out to 84.3 kW (4799 BTU/min) and 100.6 kW (5723 BTU/min).

Temperature measurements were made using 1.57 mm (0.062 inch) diameter, stainless steel sheathed, ungrounded, Type-K (nickel-chromium/nickel aluminum) thermocouples, as purchased from Omega Engineering of Stamford , Connecticut. Thermocouples were discarded after each test and replaced. Thermocouple data was digitally displayed and recorded on a 20-channel hybrid recorder (digital and paper chart recording media), Omega Engineering model DR130. Eight (8) thermocouples were used for fire environment characterization and twelve (12) were used on and in the test article.

TESTS:

<u>MDS Nordion F-458 Unit #7 Test date: 2/28/2001</u>

Fred Taylor of MDS Nordion and Rajesh Garg of the CNSC witnessed this test. The burner was turned on at a setting of 160 PSIG. Temperatures rose very rapidly with the fire environment averaging about 871°C (1600°F) after about 10 minutes from burner start. Five minutes later some temperatures were more than 1371°C (2500°F) and thermocouples started dropping offline. The burner was turned off at about 21 minutes from burner start when molten stainless steel started flowing onto the floor.

A post-mortem indicated that the furnace and thermocouples were destroyed. The steel mounting rail supports for the test unit had collapsed and melted through the furnace wall. The fuel and air delivery rate combined with burning foam pyrolysis gasses had combined to create a blast furnace. The 55-gallon containment drum (furnace assembly) had a large (about 1.5 square foot) hole in the bottom and was scrapped. *Nevertheless the F-458 maintained containment and the LP1 was later shown to be leak tight to better than* 7.0×10^{-9} *std. cc/sec.*

The first fire test runs in the test apparatus used simulated packages containing no foam or just water. The F-458 package was then mounted in the furnace so that the bottom surface faced the burner. This face contained two vents that can be seen in Figure 2 below as the areas on the top face of the unit where foam char has escaped. A short time into the test, the foam gases exited the package through these vents and burned just above the burner flame, increasing the heat input, gas velocity, and ambient temperature. In a pool fire environment, these burning gases would be directed downward and away from the package, but in the test, the gases were directed around the package and out the chimney.

During the 30 minute test approximately 13 pounds of foam were burned, or an estimated 0.43 lbs/min. Without reducing the rate of fuel oil consumption, the test apparatus became a blast furnace, melting the stainless steel covering of the package at temperatures exceeding 1538°C (2800°F). The test apparatus gas velocity, ambient temperature, and heat transfer to the F-458 exceeded the regulatory requirements.

After the following hardware and procedural changes, we decided to try again:

- The test article support was extended through the drum and welded to heavy supporting structure.

- The burner would be throttled back to as low as 70 PSIG fuel pressure and the burner damper adjusted as necessary to assure stoichiometric combustion, as determined from thermocouple temperatures and from the observation of smoke and stack gasses, which should show evidence of burning as it exits the stack (as opposed to burning only after mixing with outside air).

MDS Nordion F-458 Unit #5 Test Date: 5/10/2001 (**Regulatory Burn**)

F-458 Unit #5 had thermocouples in 12 locations and the fire environment in 8 locations. The burner was initially set at 160 PSIG fuel pressure with the air damper open. Heat built up rapidly. Thermocouple #4 was lost immediately- a probable wiring short in the leads, which would account for an ambient temperature reading throughout the test. At 10.86 minutes from burner start, the 7 remaining environmental thermocouples averaged 808°C (1487°F) and the test timer was started. Fuel pump pressure was quickly adjusted (reduced), over a period of ~2 minutes, from 160 to 70 PSIG and the damper adjusted to reduce the air into the burner to bring it in line with the reduced fuel flow. These adjustments were very effective and the *average* temperature of the environmental thermocouples slowly crept up to as high as 997°C (1826°F) as the test progressed. A popping noise was heard at about 38 minutes into the test, which was otherwise uneventful. At 42.08 minutes the burner was turned off. The environmental thermocouples averaged 802 °C (1475°F) at 44.76 min. resulting in a test time of 33.9 minutes. The burner cone was then removed form the furnace opening, allowing the test article to cool naturally. Figure 2 shows the mounted test article after the cool down.

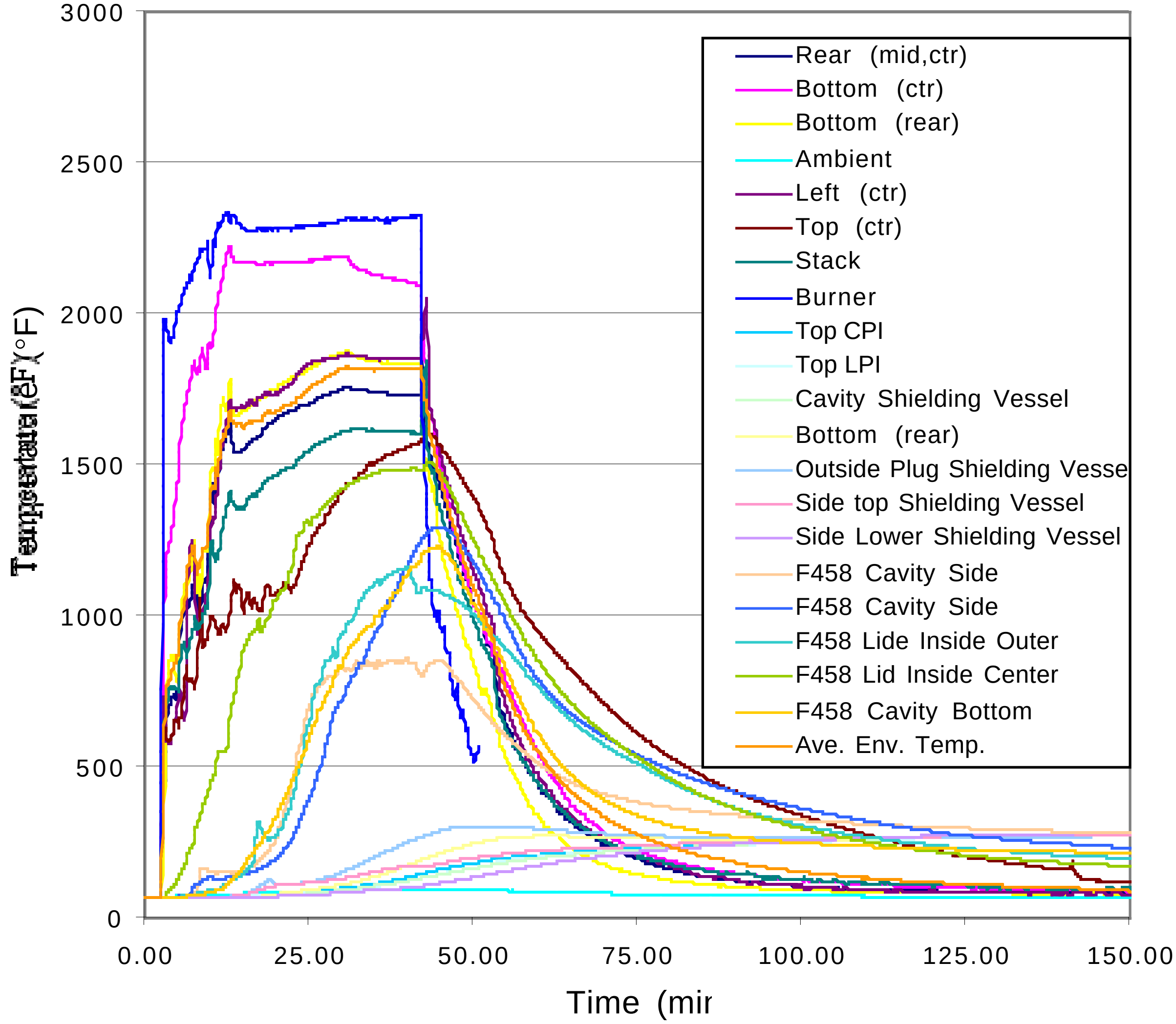
FIGURE 2: Mounted Test Article Post-Test

Tpl#	Location
1	Rear Center of 55 gallon containment drum
2	Bottom longitudinal middle of 55 gallon containment drum
3	Bottom rear of 55 gallon drum containment
4	Right side, longitudinal middle of 55-gallon containment drum. This tpl. was lost during the test (but does indicate ambient room temperature outside of the test hood)
5	Left side, longitudinal middle of 55-gallon containment drum
6	Top longitudinal middle of 55 gallon containment drum
7	Stack (where burning gasses exit the 55 gallon containment drum)
8	Burner (4 inches from burner cone)

The above fire environment thermocouple junctions were located approximately 25.4 mm to 38.1 mm (1 to 1.5 inches) from the inside of the 55 gallon drum containment (furnace) wall and a few inches from the test article. The test article was positioned along the centerline of the drum with the lid pointing to the rear to facilitate routing the thermocouple wires out through the chimney. In order to diffuse the burner flame, a sheet metal baffle (drilled with large holes) was used. This baffle seemed to work quite well in distributing the burner flame around the test article.

Maximum temperatures in the unit occurred long after the burner was shut down, as shown in Figure 3.

FIGURE 3: MDS Nordion Unit #5 B



Tpl No.	Time ** (Min.)	Highest Temp. Reached (°F)	Location
9	193.37	281	Top Leak Proof Insert
10	185.35	281	Top Leak Proof Insert
11	185.35	281	Cavity Shielding Vessel
12	188.86	278	Inside Plug Shielding Vessel
13	185.35	275	Outside Plug Shielding Vessel
14	161.49	282	Side Top Shielding Vessel
15	107.84	285	Side Lower Shielding Vessel
16	37.41	856	F-458 Cavity Side
17	44.42	1297	F-458 Cavity Side
18	39.91	1160	F-458 Lid Inside Outer
19	43.25	1508	F-458 Lid inside Center
20	44.59	1230	F-458 Cavity Bottom

** Note: times are from burner start

COSTS:

The laboratory scale for this testing resulted in considerable savings. The test can be set up in an existing hood (of sufficient size) to burn several units for a cost of about $20,000 to $25,000.

SUMMARY AND CONCLUSIONS:

This testing methodology closely approximates that of a full size pool fire with the severity prescribed in IAEA, TS-R-1, par 728. In particular, the use of a “dirty,” oil-fired flame possessing a characteristically intense radiant component replicates the pool fire environment. This flame, together with air intake damper adjustments that preclude anoxic fire conditions and provide for higher gas flow rates past the test article, better simulates a regulatory fire than exposure in a heat treat furnace. The maximum diameter of test article that can be effectively evaluated in this apparatus would be 43 cm (17 inches); thus permitting adequate flow around the test article in the confined space of the test drum “furnace.”

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ACKNOWLEDGMENTS:

The authors wish to give special thanks to Charles Williamson at General Plastics Manufacturing Company and Jim White of Western Fire Center for their contributions to this effort.