Proceedings of the 19th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2019
August 4-9, 2019, New Orleans, LA, USA

FIRE TESTS OF RAM PACKAGES AND CONTAINERS UNDER HIGH THERMAL LOADS

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ABSTRACT

Fire testing is an essential part of the hypothetical, cumulative mechanical and thermal test conditions that shall guarantee package safety in severe accidents. Within regulatory approval of transport or storage packages for radioactive material, specific thermal load tests are required in accordance to licensing conditions and international standards, respectively. The specifications of these thermal tests are based on test conditions with equivalent heat input to that of a hydrocarbon fuel fire. In the past, light heating oil, diesel or kerosene was mostly used as the fuel to generate the pool fire. In accordance with IAEA regulations for a fire in an accident, the temperature of 800 °C over a period of 30 minutes must be fulfilled. Furthermore, the delivery acceptance criteria for containers in nuclear waste repositories could reach for example average temperatures of 800 °C during a period of one hour in combination with defined requirements on activity release.

BAM as a scientific and technical German federal government institute operates an open air Technical Safety Test Site for experimental investigations of dangerous good and its containment. In this areal a large fire test facility is under operation. Liquid Propane is utilized as fuel which is pumped via pipelines from a central storage tank to the fire exposed test facility areas. In the ring burner system, the gas is released from nozzles, and ignited by ignition burners.

The paper includes examples of fire test performance with prototypes of a transport package and a storage container, respectively. In preparation of the thermal load, calorimeter tests have been performed using test specimens of appropriate size and behavior. For the fire test scenario is demonstrated that the IAEA thermal test requirements are fulfilled.

INTRODUCTION

BAM, the German Federal Institute for Materials Research and Testing is involved in the mechanical and thermal safety assessment of transport packages for high and intermediate radioactive material, as well as of containers for the final disposal of low and intermediate level radioactive waste. The design and safety evaluation process may include drop tests and fire testing in accordance with national and international regulations, which are based on IAEA regulations [1] or even on specific requirements derived from acceptance criteria of the final disposal site [2].

For a packaging which has subjected to the most severe damage condition in a hypothetical transport accident, a full engulfing fire with temperature of 800°C over a period of 30 minutes must be fulfilled. On the other hand, the delivery acceptance criteria for waste containers in nuclear waste repository could reach for example average temperatures of 800 °C during a period of one hour in combination with defined requirements on activity release.

The specifications of these thermal tests are often based on test conditions with equivalent thermal load to that of a hydrocarbon fuel fire with approximately 75 to 110 kW/m². As per IAEA guidelines, for a fire in an accident an average heat flux of at least 75 kW/m² must be met [1]. The open-air fire test facility of BAM operates by liquid Propane as fuel. The comparability between hydrocarbon and Propane fire is shown by reference measurements of various sized tanks and containers [3].

FIRE TEST FACILITY AT BAM TTS

The fire test area at BAM's open-air Test Site Technical Safety (TTS) consists of two separate fire test facilities (Fig. 1) which are described in detail in [4]. Furthermore, an open-air drop tower for containers and packages with gross weight up to 55 metric tons is located on the same test field very close to fire test facility 'A', see Fig. 1.

In both fire test facilities Propane is utilized as fuel which is pumped through several pumps via underground pipelines from a central storage tank to the fire exposed test area. Generally, destructive fire test with hazardous materials pressure vessel are performed in fire test facility 'B'. Thermal tests of transport packages and waste container for radioactive material are carried out in fire test facility 'A'. The constructional design of fire test facility 'A' corresponds to full-scale test objects with a mass up to 200 metric tons, which can be drop tested using BAM's large drop tower next to the fire test area at BAM TTS [5].

THERMAL TEST SETUP

The firing is based on the principle of a ring burner system positioned in distance of about 1 to 3 meters from the test sample. Here the Propane gas mixture is released from nozzles, and ignited by ignition burners. The burner system can be adjusted to the size and geometry of the test object up to a maximum surface area of 8 m x 12 m. The sample is positioned on a massive rack which stands on a flat concrete surface in appropriate distance to the burner ring and nozzles. A permanent water circulation system cools the concrete base of the test stand. The intensity of heat flux can be regulated by variation of pressure and throughput volume of Propane. The nozzle arrangement ensures that the test sample is fully engulfed in fire. Fire peak temperatures up to 1.100°C are reached depending on experimental conditions. The effect of side wind can be minimized using wind deflector plates made of heat-resistant steel sheets.

In order to fulfil the required fire conditions, the parameters of the burner configuration and the amount of propane consumption are determined in advance. The determination is done by an equivalent heat input test by means of calorimetric principle with an appropriate full-scale model of the container to be fire tested. The thermal test models are made of welded steel sheets and filled with water. The heat input tests are performed with full engulfment of the test models reaching heat fluxes of 75 kW/m².

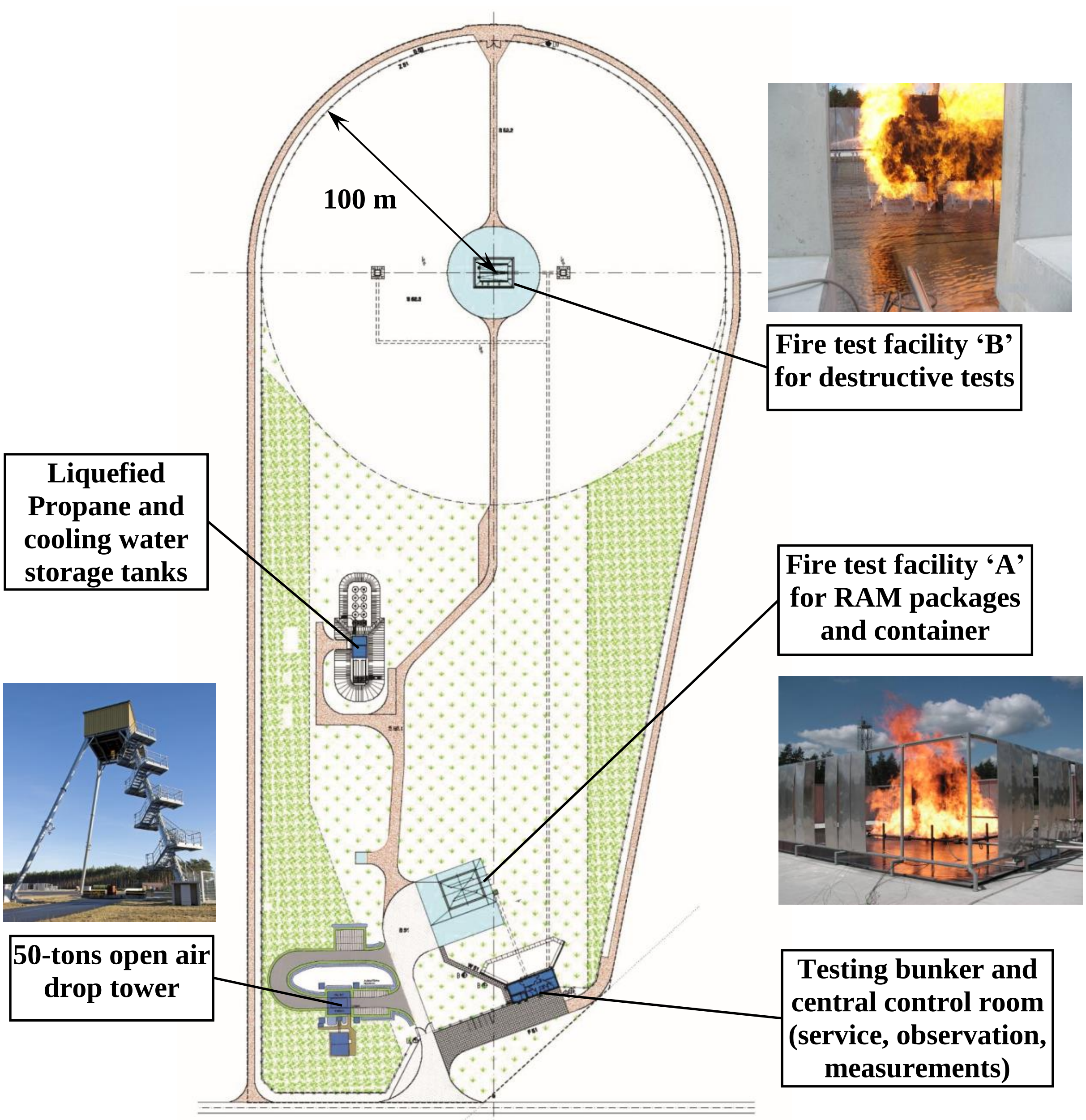

Fig. 1. Site plan of the large fire test areal at BAM Test Site Technical Safety

Table 1. Setup and conditions for thermal test of test container in fire test facility "A"

Thermal test setup and conditions	**Test specimen TC 1**	**Test specimen TC 2**
Test sample	Cubical container	Cylindrical container
- dimensions	1.900 x 2.000 x 1.800 mm³	2.400 x 1.100 mm²
- weight	26.000 kg (empty)	4.000 kg (gross weight)
- material (outer shell)	cast iron	stainless steel
Position in fire	bottom-down on a test stand	horizontal on a test stand
		
Ring burner system	6 x 6 m with 28 nozzles	4 x 5 m with 8 nozzles
Propane output rate	3.400 kg/hour	1.800 kg/hour
Pre-Temperature of sample	ambient temperature	pre-heated 65 °C
		
Temperature-time regime	800 °C over a period of 30 min	800 °C over a period of 30 min
Heat flux	75 kW/m²	75 kW/m²
Fire characteristic	Full engulfment of TC1	Full engulfment of TC2
Mean fire temperature	ca. 870 °C	ca. 900 °C
Max. fire temperature	1.100 °C (100 mm distance)	1.082 °C (100 mm distance)

TEMPERATURE MEASUREMENT

A detailed description of the verification of the fire conditions can be found in [4]. Fire exposure conditions have been tested comprehensively by various burner configuration and fuel flow rate for their degree of engulfment, uniformity of heating, and the susceptibility to wind effects [6].

The thermal test is performed with instrumented test sample adapted to the aims of the test. The effective and average flame temperatures were measured by temperature sensors continuously with a 10 to 100 cm distance to the surfaces of the specimen. Furthermore, specific design features of the specimens like sealing or closure cover and plugs or valves are controlled by temperature sensors during pre-heating, fire and natural cooling.

Test samples are instrumented with calibrated mantle thermocouples of type Ni-CrNi with outer diameter of 1,5 mm and 3 mm, respectively. Data acquisition of the sensor signals is carried out by using a multi-channel measuring device. In addition, the weather conditions (wind speed and ambient temperature) are recorded continuously with a sample rate of 60 s during the whole fire test and the natural cooling down phase.

The test setup and parameters for both test scenarios are summarized in Table 1 including photos of the test samples and fire test performance. As a result, a typical temperature-time sequence is shown in Fig. 2.

RESULTS AND DISCUSSION

The fire temperatures at the points of measurement in the distance of approx. 100 mm to the outer surface of the test containers increase rapidly after igniting of the ring burner system. The fire test temperature of 800 °C is reached after a period of ca. four minutes, see Fig. 2.

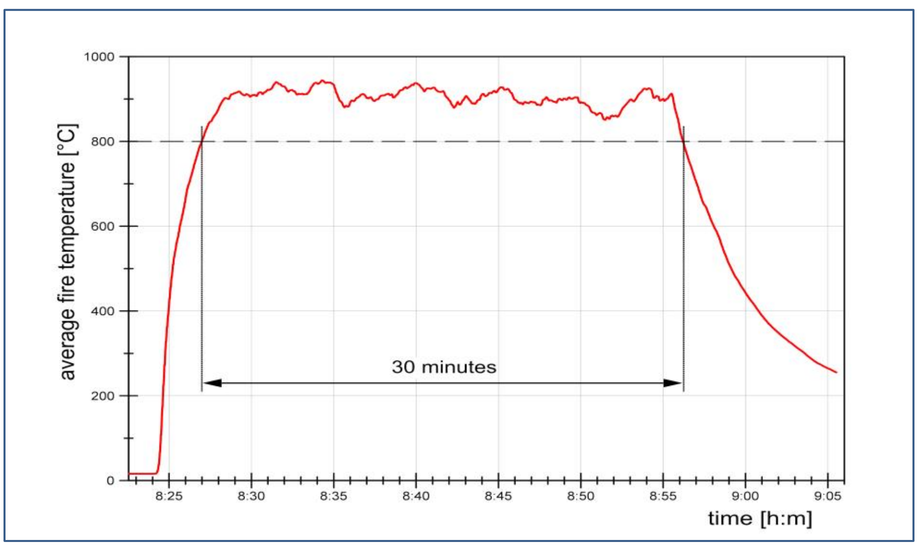

Fig. 2. Temperature-time curve of the average fire temperature during thermal test

During the testing period of 30 minutes the average of the mean fire temperatures amounts to approximately 900 C. While the highest fire temperature of 1.100 °C is recorded at a single measurement 100 mm from the surface of the test sample.

In open air fire tests, continuously recording of wind conditions together with the measured fire temperature curves are indicated as a role that wind speeds greater than 2 ms^{-1} resulted in disruptive effects for the flame thickness and engulfment of the test sample which could let to a locally offset of fire temperature.

CONCLUSION

The fire test conditions generated for the test containers show a very good accordance with the thermal test requirements of international regulations. The heat flux of 75 kW/m^2 is achieved with a propane fire and the test containers are engulfed in the flames using suitable arrangement of the nozzles and a gas release rate which is adapted to the test samples in advance by appropriate calorimetric tests.

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