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Thermal tests of a CP5.2 packaging system: Prototype and experimental test description

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ABSTRACT

Managing radioactive waste must be carried out within a strict framework and with a constant requirement to protect human beings and the environment. A safety management of the radioactive material or waste (RAM or RW) unavoidably involves transportation activities by using robust safe and reliable packaging system. The integrity is a crucial aspect in the design of these systems; to certify it packages should demonstrate to withstand loads, that could occur under normal and accident conditions, and to meet the safety requirements in terms of performances of containment and radiation protection, like the IAEA ones.

This study deals with the thermal performances of an Italian CP5.2 packaging system aimed at the transportation of bituminised wastes, which have been evaluated by executing experimental tests in the fire scenario as specified in the IAEA regulations (i.e. engulfing fire of 800 °C for 30 min).

To the purpose a dedicated small scale mock-up has been designed and built at the Dept. DICI of the University of Pisa. The experimental test allowed to set up the test procedure to be adopted for the fire tests of a large scale system in consideration of risk related to the stowed bituminised wastes.

The results of the thermal test are presented and discussed. They showed that after half an hour of exposure at 800 °C the temperature in the bituminised waste package is about 100 °C (below that of auto-ignition), and the maximum temperature at the cement mortar is below 400 °C.

Analysing the measured temperatures and caused effects it is possible to conclude that the overall integrity of the packaging system is assured.

1. Introduction

About 20 million consignments of radioactive material take place around the world each year (IAEA, 2012); in doing that an essential component is a robust safe and reliable packaging system that is constituted, in general, by a relatively massive sealed steel structure.

The waste package, made from metals, concrete, polymers or composite materials, in which the waste form is placed for transport and/or storage, has key roles to play in the several stages of the waste management process. To safely transport radioactive materials it is required that the packaging system must be able to guarantee the containment and the confinement (integrity assurance) of the radioactive material or waste (RAM or RW) avoiding any additional dose exposure (respect of ALARA principle).

The packaging (Fig. 1) must be designed according to the activity, and the physical and chemical form of the waste material (e.g., raw solid wastes, wastes immobilized in cement or bitumen and compacted pellets immobilized by grouting).

Waste containers may be designed for relatively short or long lives, depending on the role they will have in disposal: in the first case, packaging can be classified as non-durable (life of a few tens of years) and would play no role as a barrier to radionuclide release. In the second case, the container has to guarantee the confinement of radionuclides.

This study has the main objectives of verifying the main requirements for the design of waste containers, in which wastes are immobilized in bitumen, and to provide advice/recommendations concerning the design and testing (qualification process).

Due to the peculiarity of the waste form used to immobilise RW, whose variation can significantly affect the properties of the overall Italian CP5.2 package, in this study the emphasis is on the evaluation of its thermal performance in order to ensure that the containment is as effective as possible. In this framework, the design requirements set forth by the National Safety Authority and, in general, by International Atomic Energy Agency (IAEA) in (IAEA, 2012) (in Italy (UNI, 2011) and (ENEA, 1987)) are considered.

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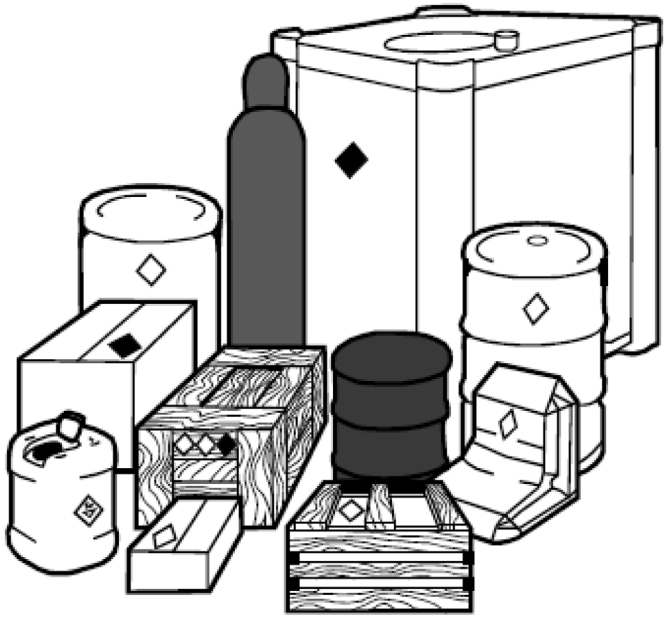

Fig. 1. Overview of package types.

The proposed study is structured in four main sections. Section 2 provides a short description of the requirements to be fulfilled to meet the CP 5.2 packaging design criteria. Section 3 provides a description of the characteristics of the dedicated mock-up designed and built at the DICI of the University of Pisa Italian CP5.2 packaging system. Section 4 describes the procedures of the performed experimental fire test, as specified in the 2012, IAEA SSR-6 regulations (i.e. engulfing fire of 800 °C for 30 min), and a discussion of the results obtained.

It is finally worthy to note that the economic feasibility of the CP5.2 packaging system is not provided in the following since that it is out of the scope of the study.

1.1. Literature summary

The integrity of packaging is crucial for a safe disposal, storage and transport of RAM/RW: to certify it the manufactures or "applicant for approval" are required to demonstrate that these packaging systems can withstand loads, that could occur under normal operation and accident conditions (Lo Frano et al., 2011; Rains D.J., 1999; Lo Frano and Sanfiorenzo, 2016), and meet the safety requirements in terms of confinement, containment, and radiation protection.

Table 1
Prismatic Package dimensions.

Type	Volume [m^3]	Height [mm]	Length [mm]	Width [mm]
CP-2.6	2.6	1250	1650	1250
CP-5.2	5.2	1250	2500	1650

Lo Frano et al., 2011 and Pugliese et al., 2010 investigated the thermo-mechanical behaviour of a cask undergoing respectively in normal condition of transport (for dry and wet storage condition) and in accidental one. He focused on fire test and post-accident cooling phase and described the induced effects of such a type of accident scenario. Kim et al., 2010 studied the performance of an IP-2 prismatic package designed to contain up to eight 200-L steel drums so to provide a mid-step in demonstrating the package performance and predict the package behaviour during the drop tests. Rains, 1999 provided a technical evaluation of a spent nuclear fuel multi-canister overpack; however, this work focused only on the overpack performance undergoing free drop test. Lo Frano et al. (2014) presented and briefly described the IAEA (2012) test procedure for demonstration numerically of the structural performance of an Italian IP2 package (qualification and reliability) packaging for ILLW.

Despite to immobilise RWs in bitumen was a treatment technique used in the past, it is worthy to remark that this investigation is quite new in the nuclear field because of the lack of the studies concerning the issues evolving during the normal and accident transport/storage conditions.

2. Requirements for packagings and packages

Before packages were firstly used, qualification tests or corresponding validated numerical simulations, covering normal and accident situations, which can be realistically envisaged in order to guarantee safety throughout the package lifetime, must be done to demonstrate their ability to withstand such conditions of transport. In particular, the accident conditions (Fig. 2) to be taken into account are:

1) Mechanical test, that consists of the three different drop tests:
   1.1) horizontal, slap down, vertical, and oblique 9 m drop tests onto

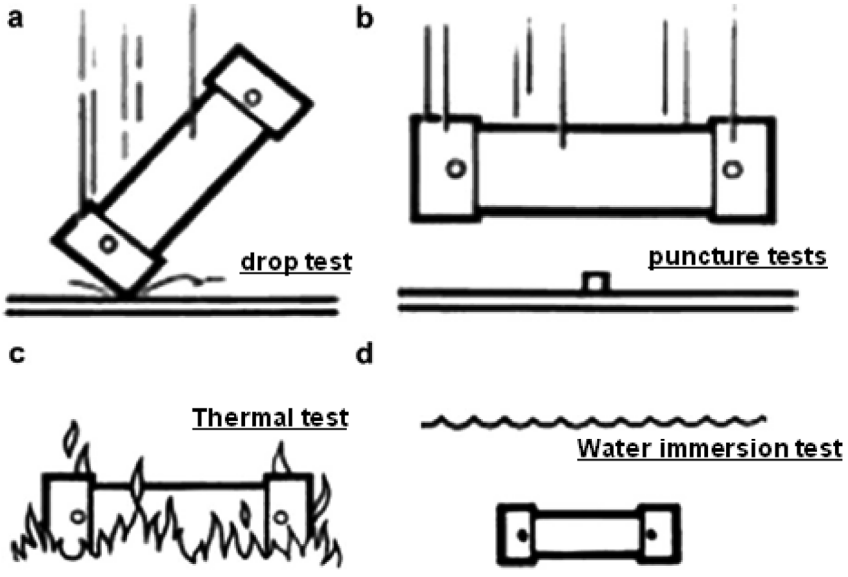

Fig. 2. Sequence of possible accident conditions according to IAEA requirements.