Applicability of Epoxy Resin-Based, Neutron-Shielding Material to Spent Nuclear Fuel Cask

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INTRODUCTION

Neutron–shielding material for the spent–fuel cask is required for good heat–resistivity and mechanical strength as structural members in addition to the neutron–shielding property. Epoxy–resin–based neutron shielding material, NS–4–FR, which is owned and supplied by Tokyo–based Genden Engineering Services & Construction Company (GESC), is known as one of the remarkable materials with these characteristics.

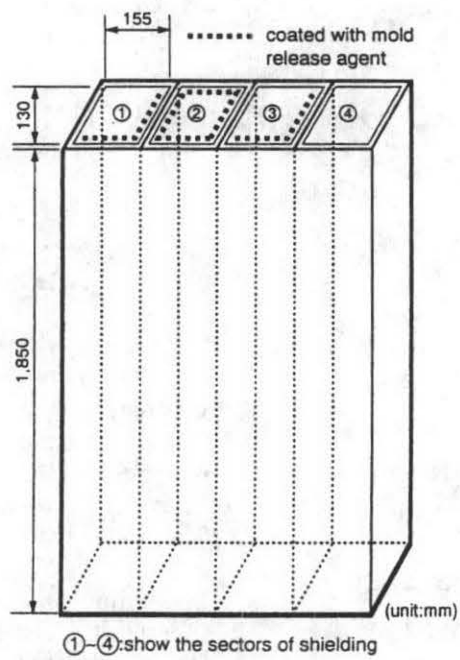

Figure 1. Dimension of Partial Mockup of Spent- fuel Cask.

A demonstration test of the installatin of NS–4–FR was performed using a partial mockup of a transport cask in

August 1994. The aim of the test was to obtain technical experiences to establish the procedures for the installation, from the point of view of efficiency of the work and quality assurance. The mockup is made of mild steel and consists of four chambers, which simulates four sectors of the shielding spaces of the cask to be poured and filled with raw liquid material of the shielding. The dimension of the mockup is shown in Figure 1.

Table 1. Theoretical Elemental Composition of NS-4-FR.

B4C Content	0	1.2 (%w/w)
Hydrogen	6.0	5.9
Carbon	27.7	27.6
Oxygen	42.8	42.3
Aluminium	21.5	21.2
Nitrogen	2.0	2.0
Boron-10	—	0.17
Boron-11	—	0.77

OUTLINE OF THE SHIELDING MATERIAL

The NS-4-FR kit comprises three kinds of the ingredients: part 1, liquid epoxy resin; part 2, epoxy resin curing agent (liquid); and part 3, powder part with B4C. Each part is contained in a drum.

The theoretical elemental composition of the material and the major physical properties are shown in Tables 1 and 2, respectively.

Table 2. Major Physical Properties of NS-4-FR. (B4C 0 %w/w)

Specific Gravity (g/cm^3)	1.67
Ultimate Tensile Strength (MPa)	28
Ultimate Compressive Strength (MPa)	72
Linear Thermal Expansion Coefficient (1/K)	1.1×10^{-4}
Thermal Conductivity (W/mK)	0.65
Thermal Capacity (kJ/kgK)	1.0
Color	Dark Brown
Maximun Continuous Operating Temperature (℃)	150
Radiation Resistivity	Good
Heat Resistivity	Good
Pot Life (hour)	2 (at 25℃)
Curing Time (hour)	10 (at 25℃)

INSTALLATION OF SHIELDING

Before the installation, the resin mold release agent was coated on some of the inner surfaces of the mockup chambers as shown in Figure 1 to cope with the curing shrinkage. On installaton of NS–4–FR, the liquid parts, part 1 and part 2, were mixed and stirred first in a drum, and then the part 3 was added slowly and the mixture was stirred further. After the three parts were mixed uniformly, the drum was moved and set in a vacuum chamber for defoaming. A vacuum pump was used for the defoaming. The specific gravity of the raw liquid material (wet specific gravity) was measured and confirmed to be above the standard value (1.62 g/cm^3 in this case) before it was poured into the chambers.

A kind of slurry pump was used for the pouring operation. The liquid material was transferred into the hopper of the pump, and it was pumped up into the chambers of the mockup through a vinyl hose. To investigate that the pouring operation for one chamber can be performed in steps, the installation for some chambers were divided into steps. The time intervals between two subsequent steps are shown in Figure 2. All the equipment, the mockup and the NS–4–FR kits were enclosed in a clean–house with air conditioners, and the ambient temperature was kept around 25°C throughout the test.

About eight kits of NS–4–FR (30 kg/kit) were used for the test. After the material cured sufficiently, mild steel lids were welded to the tops of the chambers. The mockup with the shielding material was cut into some pieces to observe the uniformity of the shielding and the effect of the heat to the shielding added during the welding. Samples were taken from the shielding for physical and chemical property examinations.

RESULTS

1. For the mixing operation of the three parts, it is desired to keep the material and ambient temperature at around 25°C, to facilitate workability and curing time.

2. Degree and duration of vacuum should be controlled carefully for appropriate defoaming. The principle which was applied for this demonstration was "Not less than 2 minutes at approximately zero atomospheric pressure."

3. If the defoaming is performed properly, the wet specific gravity of the material is above the standard value. And if the wet specific gravity is above the standard value, the relevant solid-state specific gravity (dry specific gravity) is not less than standard value (1.67 g/cm^3).

4. The effect of the mold release agent confirmed that the dried resin adjacent to the inner surfaces coated with the agent parted from the surfaces clearly, whereas those adjacent to the surfaces without the agent adhered firmly to the surfaces.

5. The pouring operation for one chamber can be performed in steps. If the time interval between two subsequent steps is about 2 hours, no distinct line and mark were observed around the boundary of the steps in the mockup test.

6. No discoloration and sign of degradation of the installed shielding were observerd near the welded parts.

7. No distinct nonuniformity of the dry specific gravity and hydrogen content was observed in the installed shielding material as shown in Figure 2.

8. No distinct segregation of B4C was observed in the installed shielding material as shown in Figure 2.

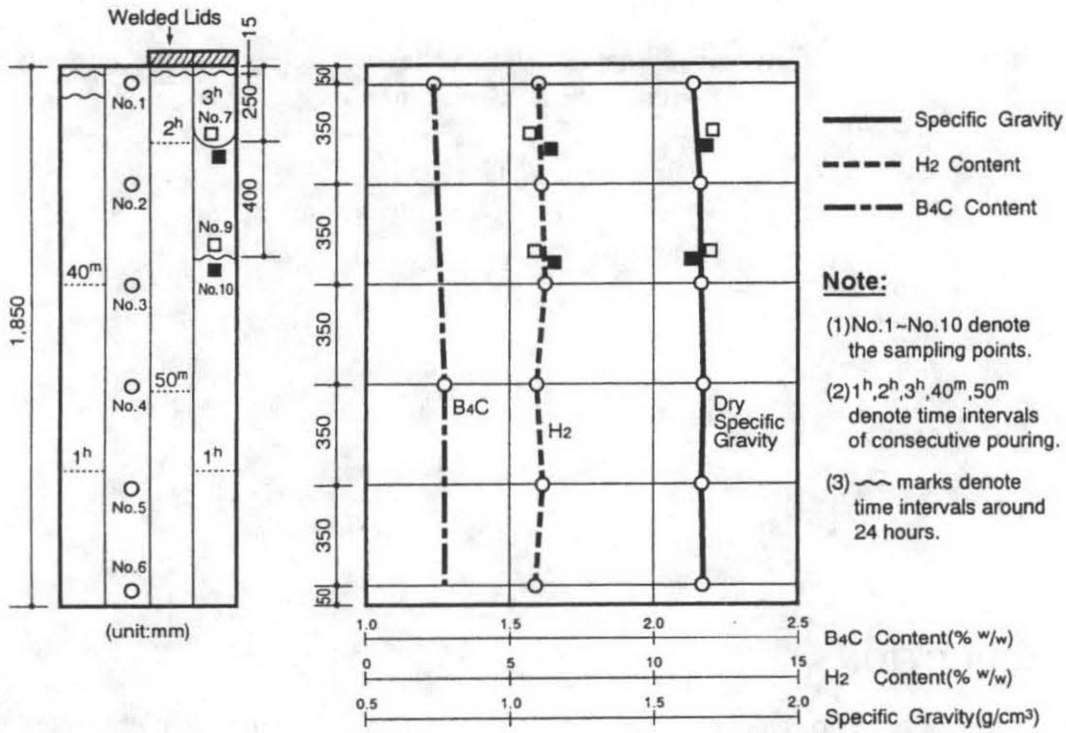

Figure 2. Axial Distribution of Dry Specific Gravity, H_2 and B_4C.