ENSA (Grupo SEPI)

Fabrication Thermal Test. Methodology for a Safe Cask Thermal Performance

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Outline

- Introduction
- Thermal Test Analytical Model
- Fabrication Thermal Test
- Results and Conclusions

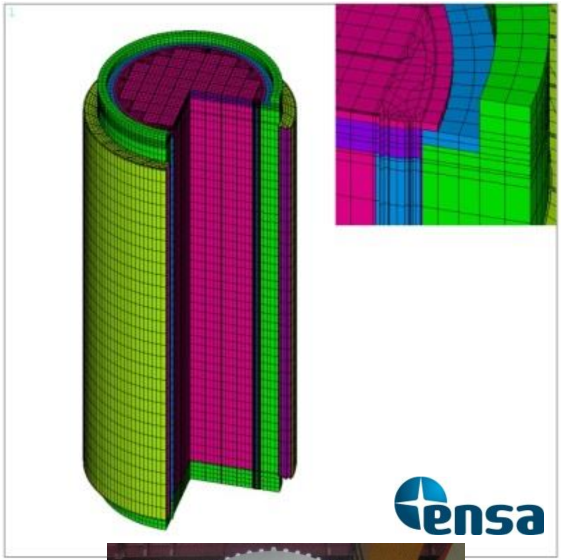
Introduction

- Thermal is one of the Safety Related Functions of a Spent Fuel Storage and/or Transportation Cask
- Cask Thermal Performance shall be assured both in normal and accident conditions. Confirmatory tests are required (but not mandatory) in the transport regulations for HAC and may be required (low priority) for storage
- Traditionally, the thermal behavior relies on analyses due to the difficulties of the thermal tests, although…..
- Many regulators require, as part of the licensing process, a fabrication thermal test on the first unit manufactured
- Goals: 1) model validation, and 2) thermal performance

Thermal Test Analytical Model

- Model validation is the first goal of this methodology
- Finite Element Model (FEM) of the cask is used in the analysis, which intends to simulate the real behavior of a loaded (heaters) cask during the fabrication thermal test
- Different assumptions, engineering approaches, boundary conditions and material properties used for cask licensing thermal evaluation are applied in this analysis and will be confirmed and validated with the subsequent fabrication thermal test

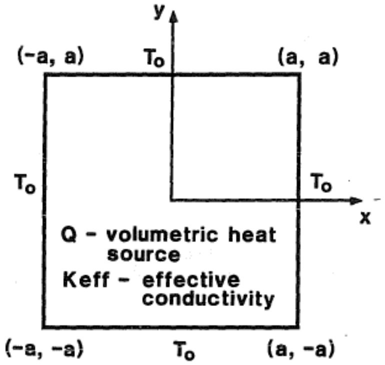
Finite Element Model Description

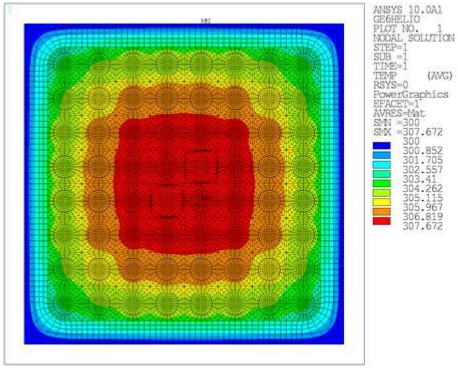


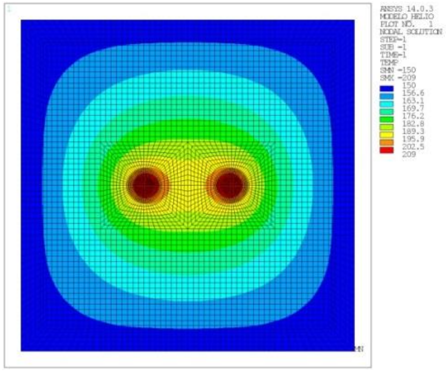
ENSA - ENUN 52B Dual Purpose Cask

- A few differences are being considered to adjust the model to the cask thermal test configuration
  - Cask inner and outer lids are replaced by a single lid
  - Trunnions are not modelled
  - Fuel Assembly equivalent material is replaced by the electrical heaters equivalent material
- Material properties are taken from the ASME Code

Finite Element Model Description (cont'd)

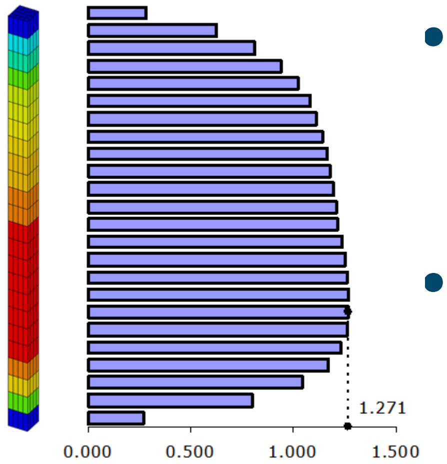


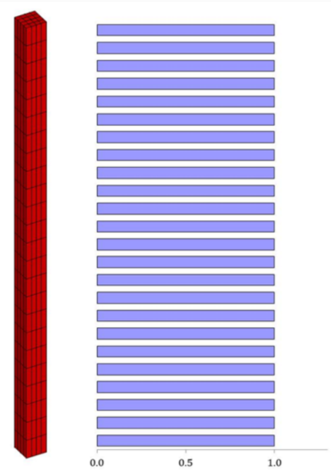




- Simulation of cask decay heat is based on electrical heaters on every basket position (52 for this particular case ENSA - ENUN 52B Dual Purpose Cask)
- Methodology for equivalent material of electrical heaters the same as for the fuel assembly equivalent material properties (Arpaci, V.S and SAND90-2406)
- Radial and axial thermal conductivity, density and specific heat are obtained with this methodology to use in the model

Finite Element Model Description (cont'd)



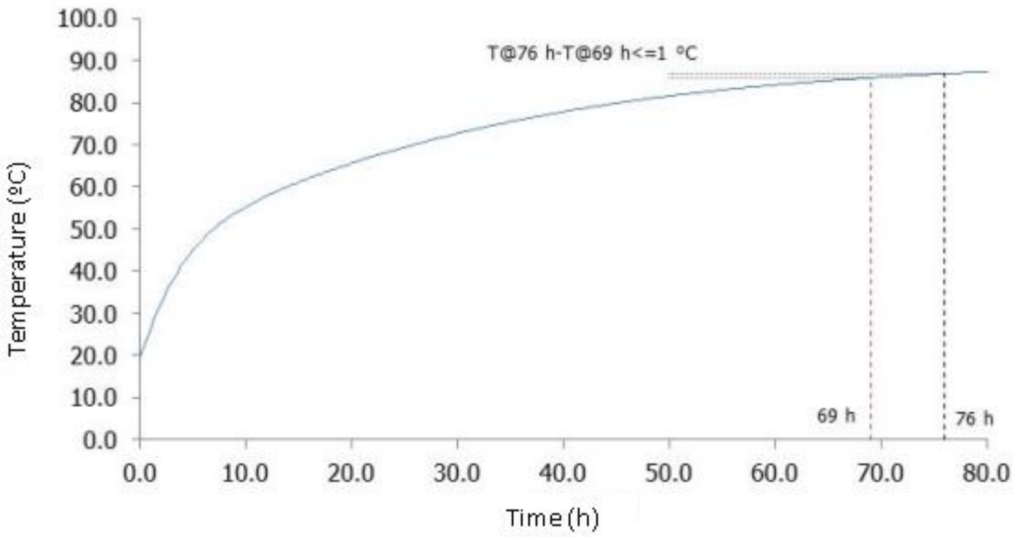


Figures are not scaled

- Fuel assembly axial thermal profile vs. electrical heater axial thermal profile (difficulties, top and bottom temperatures)
- Boundary conditions are important in this evaluation
  - Ambient temperature during thermal test (sensitivity analysis)
  - Heat transfer mechanisms inside the cask, conduction and radiation and outside the cask, convection and radiation
  - View factors for external radiation are adjusted to simulate fabrication test conditions
  - Solar radiation is not considered (test inside the fabrication shop building)

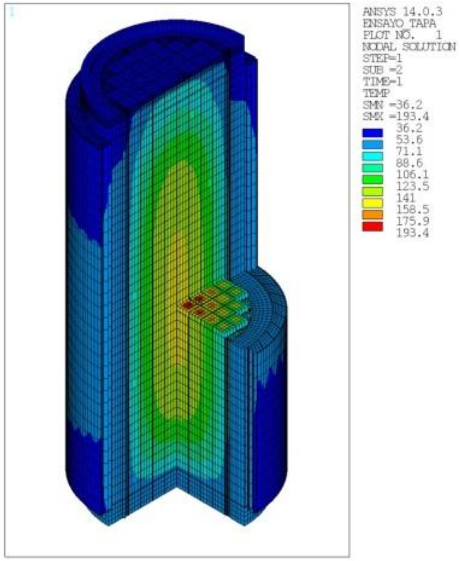
Finite Element Model Description (cont'd)

- Results of the analysis and test shall be compared with the licensing results (quasi-static), so a criterion for the thermal equilibrium shall be established
- Transient analysis is performed to obtain the duration of the test until the thermal equilibrium is reached



$$T_{thermocouples} \leq {}^{1°C}/_{7h}$$

Thermal Test Analytical Model. Results



- The quasi-static thermal test analysis provides the temperatures along the cask ("key locations") for different ambient temperatures
- Temperatures are required to be higher than those obtained in the test (conservatisms in the analysis)

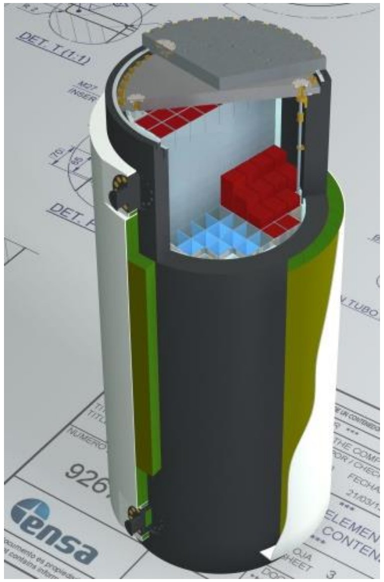
Thermocouple Location	Ambient Temperature (°C)				Normal Condition
	21	24	27	40.1	
Mid-plane Inner (EHOS)[1]	143.6	146.0	148.4	158.9	169.9
Bottom Inner Cask Body	58.5	61.2	63.8	75.4	78.9
Mid-plane Outer Cask Surface	54.4	57.1	59.7	71.2	77.4
Bottom Outer Cask Surface	49.1	51.7	54.4	66.0	71.6

[1] EHOS = Electrical Heater Outer Surface

Fabrication Thermal Test

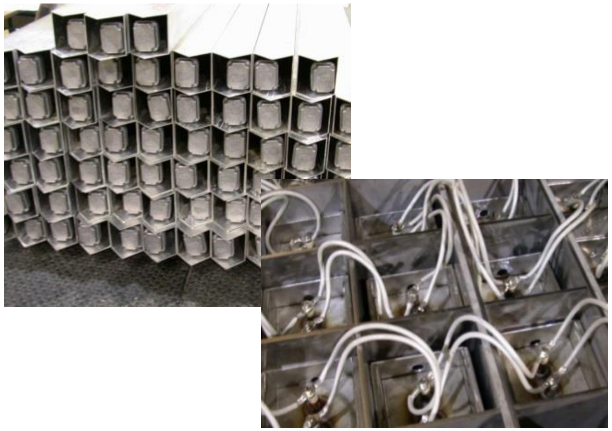
- Test to validate analytical methodology
  - Assumptions in the model
  - Boundary conditions
  - Material properties
  - Level of conservatisms
- Test to confirm appropriate cask thermal performance
- The more you know the better you understand
- Having the chance to do so, it is always a good practice to carry out test before operation, when feasible, to demonstrate safety related response of a new cask design

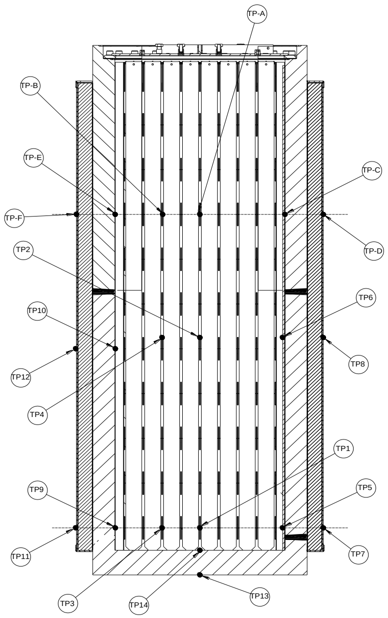
Cask Preparation for Thermal Test

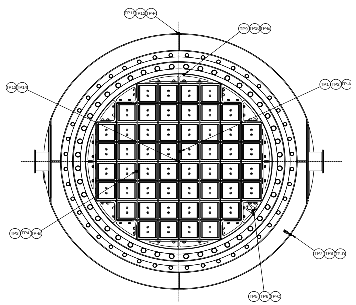


- First unit manufactured of every new cask design
- Test will be representing the normal condition of Storage
- Thermal test is one of the latest activities of the cask fabrication schedule, so the cask shall be in final condition
- Only final helium leak test is to be done after thermal test and before delivery
- All previous QA inspections confirm the compliance with design and fabrication requirements

Cask Preparation for Thermal Test (cont'd)







- Fifty-two (52) electrical heaters to simulate the maximum design thermal decay heat
- These heaters are interconnected in four groups, and each group is connected to an independent power station
- Temperature is recorded in "key" locations of the cask body, basket and heaters using calibrated type "K" thermocouples

Cask Preparation for Thermal Test (cont'd)

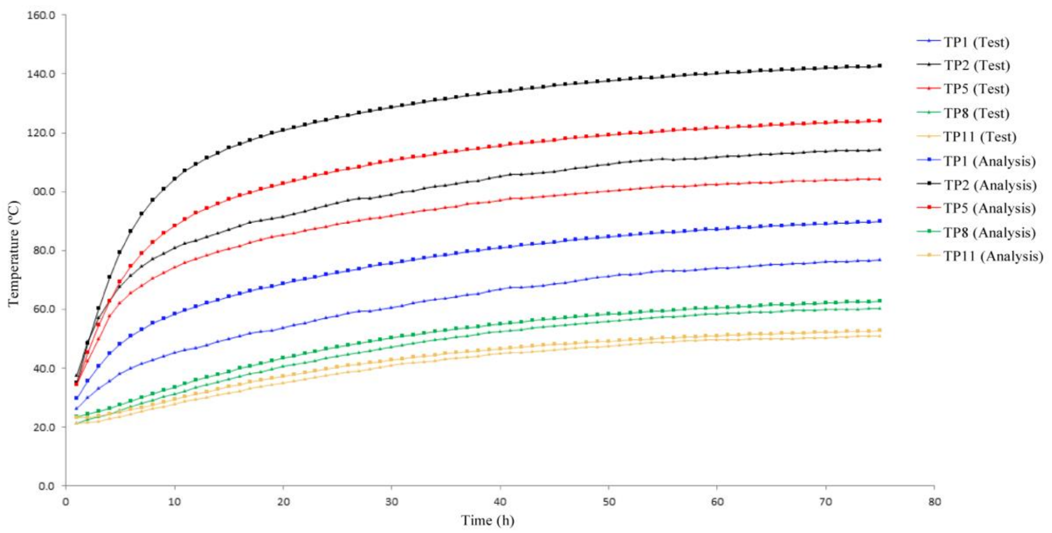
- Design of the thermal test lid is a challenge
  - Same or almost same equivalent thermal conductivity
  - Allow the instrumentation coming out from the inner cask cavity, while maintaining…
  - Leak tightness for vacuum and inert gas filling (helium)
  - Maintain test pressure during the test duration

Results and Conclusions

- After 73 h (76 h were predicted in the transient analysis) the thermal equilibrium criterion was reached
- Small leakage every 12 h was detected and refilled was required
- Temperature on every thermocouple was continuously registered

RESULTS (Temperature in °C)

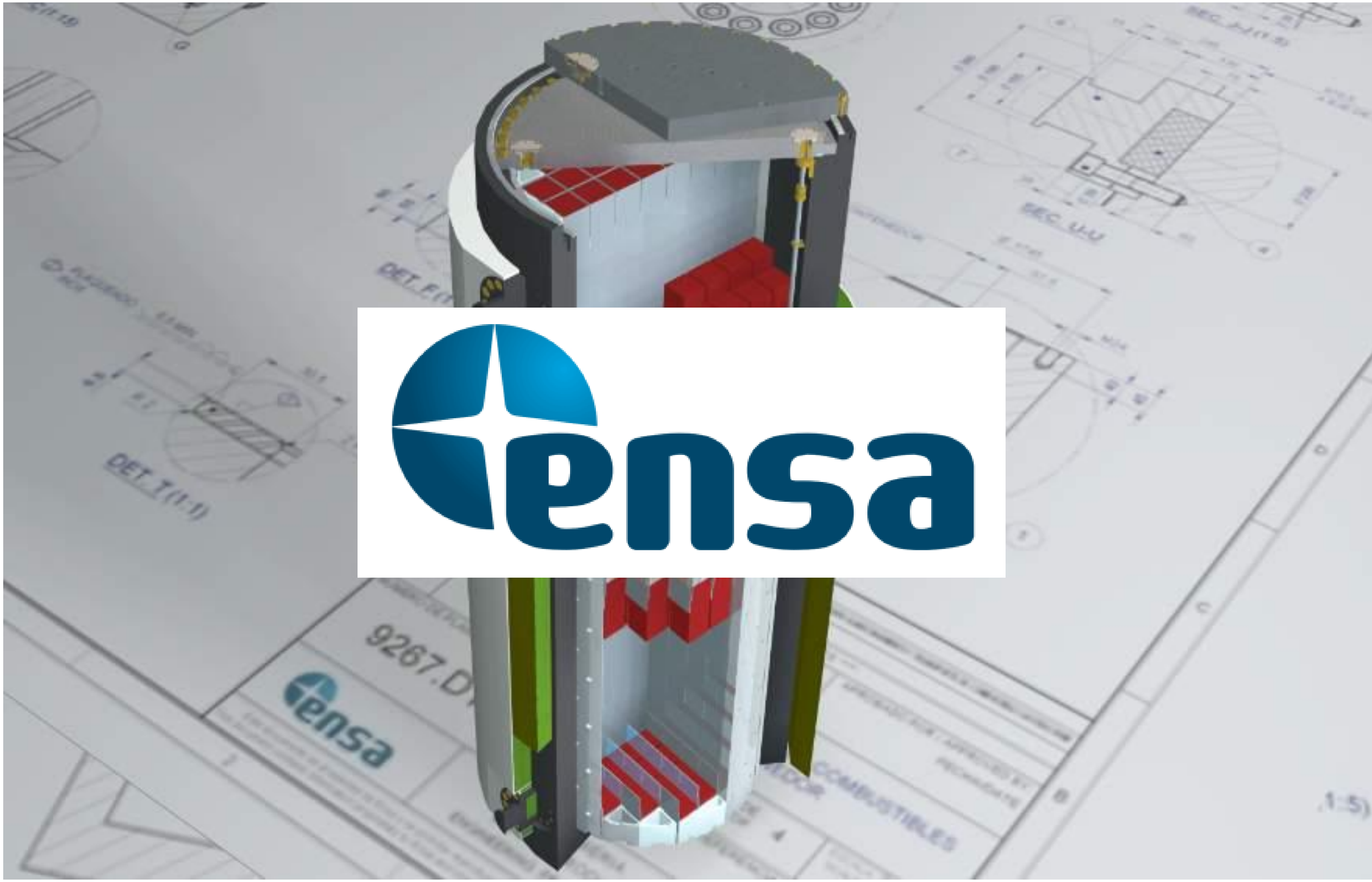
TC	Thermal Test	Analytical Model	ΔT
TP1	76.8	93.5	16.7
TP2	114.3	146	31.7
TP3	69.9	87.1	17.2
TP4	104.3	128.8	24.5
TP5	52.9	61.2	8.3
TP6	60.4	68.3	7.9
TP7	46.5	52.6	6.1
TP8	51	57.1	6.1
TP9	56.2	64.9	8.7
TP10	68.1	76.2	8.1
TP11	45.8	51.7	5.9
TP12	51	55.2	4.2
TP13	59.5	66.4	6.9
TP14	61.9	68	6.1



Results and Conclusions (cont'd)

- Calculated temperatures in all "key locations" are higher than temperatures from the thermal test
- Assumptions and engineering approaches taken in the analytical model are conservative, providing enough confident on analytical evaluations when test are not possible
- Temperatures from the calculation and from the test are in the same order of magnitude. Good correlation exists between both results
- The above mentioned confirms the two goals of this methodology: a) model validation, and b) cask thermal performance

Thanks for your attention!



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