Application of NAC Dual-Purpose Cask Technology for VVER-440 Fuel

G.T. Tjersland, T.A. Danner, D.G. Napolitano
NAC International Inc.

ABSTRACT

NAC International Inc. (NAC) has developed a dual-purpose transport and storage cask with a capacity of 85 VVER 440 type spent-fuel assemblies. The new dual-purpose cask, designated the NAC-STC(V), was developed directly from the U.S. Nuclear Regulatory Commission (NRC) licensed NAC Storable Transport Cask (NAC-STC), which is designed for the long-term storage and transport of 26 PWR fuel assemblies.

INTRODUCTION

Changes in Russian policies on the return and reprocessing of spent nuclear fuel from Soviet-supplied reactors in the countries of Eastern Europe has created significant spent-fuel management problems at a number of VVER reactors. In most cases, current spent-fuel pools have only limited storage capacities of between 4 to 6 years of fuel discharges.

To resolve these spent-fuel management problems, a number of utilities are proceeding with plans for the design, licensing, and construction of additional at-reactor Independent Spent Fuel Storage Installations (ISFSI). Responding to the need for a flexible and cost effective spent-fuel storage and transport capability, NAC developed a large capacity dual-purpose cask specifically for the VVER 440 fuel type. The NAC-STC(V) was developed directly from the design and licensing experience NAC obtained from the development of dual-purpose cask designs in the United States and Spain.

DEVELOPMENT OF THE NAC DUAL-PURPOSE CASK

NAC, in a joint development program with Empresa Nacional de Residuos Radioactivos, S.A. (ENRESA) of Spain, and Virginia Power Company and Electric Power Research Institute (EPRI) of the United States, designed and licensed the first dual-purpose cask, the NAC Storable Transport Cask (NAC-STC). The NAC-STC was designed to be in full compliance with both U.S. Nuclear Regulatory Commission (NRC) and International Atomic Energy Agency (IAEA) regulations (10CFR71; IAEA 1990) for the packaging of radioactive material for transport, and the NRC regulations (10CFR72) for dry storage of spent fuel at an ISFSI.

The NAC-STC design project was initiated in 1989 with transport approval obtained in September 1994 (NRC Certificate of Compliance No. 9235, 1994) and site-specific storage approval granted in July 1995 (USNRC 1995).

The program objective in the development of the NAC-STC was to design a cask capable of storing spent fuel for an extended period of time, 40 years or more, while requiring only minimal maintenance and monitoring, and then being capable of transporting the stored spent fuel without requiring the return of the cask to the spent-fuel pool for inspection or repackaging. The NAC-STC is also a fully capable transport cask, which can be used for transportation operations exclusively.

The key design and operational characteristics of the NAC-STC and NAC-STC(V) are presented in Table 1. The main characteristics of the licensed NAC-STC technology are:

- Multi-wall cask body construction featuring stainless steel inner and outer shells separated by a layer of lead gamma shielding;

- Solid neutron shield (NS4FR) and heat dissipation fins encased in a stainless steel shell providing a smooth, easy to decontaminate surface;

- Tube and disk basket design utilizing stainless steel structural disks, aluminum heat rejection fins, and stainless steel fuel tubes incorporating BORAL for criticality control;

- Double lid system with metallic seals incorporating pressure monitoring system; and

- Stainless steel and wood filled transport impact limiters to limit impact forces under hypothetical accident conditions of transport.

NAC-STC(V) CASK DESCRIPTION

In the early 1990's as the spent-fuel storage market developed in Eastern Europe, NAC initiated a review of the fuel characteristics and cask-handling capabilities at the VVER reactors. Through close communication with utility personnel, NAC cask design and operations personnel made site visits to reactor and independent fuel storage facilities to determine the normal fuel handling practices and operational capabilities in cask handling and loading. These site surveys are routinely performed by NAC to determine the dimensional and weight limitations of the cask-handling facilities in order to appropriately design a dual-purpose cask system that is easy to operate.

NAC next reviewed the VVER 440 fuel assembly characteristics and standard in-core operating characteristics to allow calculation of the decay heat and radiation source terms for the fuel assemblies at various cooling periods. The main characteristics of the VVER 440 fuel assemblies are:

Cross Section:	Hexagonal
Fuel Cross Section Across Flats:	143 mm
Number of Fuel Rods:	126
Length of Assembly:	3217 mm
Assembly Mass:	220 kg
U Mass per Assembly:	120 kg
Enrichments:	3.6 to 4.4% U^{235}
Cooling Times:	4 years for 35,000 MWD/MTU
	6 years for 45,000 MWD/MTU

The decay heat load per assembly versus cooling time for the various fuel assembly enrichments and exposures are presented in Figure 1.

It was determined early in the VVER 440 cask development project to utilize the existing NAC-STC body as the basis for the cask design. It was known at the time that the NAC-STC cask body satisfied all regulatory and Type B test requirements. NAC had completed a series of 9-meter free drop and 1-meter pin puncture tests at the test facilities of IAEA Technology, Winfrith, U.K. Therefore, we were confident that a shortened NAC-STC body would similarly satisfy all NRC and IAEA regulations for structural integrity. Therefore, the overall cask body was shortened to accommodate the length of the VVER 440 fuel assembly with appropriate allowances for thermal and radiation exposure.

From a comparative review of the fuel data and source terms for the NAC-STC design bases PWR fuel assemblies and the VVER 440 fuel assemblies, it was determined that the NAC-STC shielding thickness would be adequate for a VVER 440 capacity exceeding 90 design basis fuel assemblies. However, the hexagonal geometry of the VVER 440 required the development of a unique tube and disk basket incorporating hexagonal fuel tubes with BORAL neutron-absorbing material located on each side of the tube. The final basket design has a capacity of 85 intact VVER 440 fuel assemblies and includes nine structural disks fabricated from 17-4 PH stainless steel and 14 aluminum fins fabricated from 6061-T6 aluminum alloy.

Structural and thermal analyses of the cask design confirmed the structural adequacy of the basket and cask design while maintaining maximum fuel cladding temperatures below 300°C. Criticality analyses confirmed the criticality control capability of the NAC-STV(V) for all U^{235} enrichments currently used or planned to be utilized in VVER 440 fuel assembly design.

The overall cask is presented in Figure 2. The NAC-STC(V) cask assembly with call-outs of the major components is shown in Figure 3.

FABRICABILITY

The relatively thin-walled design (40 and 70 mm thick) of the NAC-STC(V) multi-wall cask body allows the fabrication of the cask at most major fabricators. The use of standard stainless steel materials also facilitates fabrication of the casks in the planned country of use. Large forgings or castings which may be beyond the capabilities of local manufacturers and fabricators are not required. NAC and its licensees and project partners have worked extensively to provide the necessary technology transfer to facilitate local fabrication.

CONCLUSIONS

The development of the NAC-STC(V) dual-purpose cask for VVER 440 assemblies was based on more than 15 years of spent-fuel transport and storage cask design experience. The NAC-STC(V) is a large capacity cask which meets the cask handling dimensional and weight restrictions of the reactors sites for which it was designed. The NAC-STC(V) cask design is a direct adaptation of the NRC licensed NAC-STC technology developed by NAC to satisfy the rigorous cask design and regulatory requirements of the NRC and IAEA.

The multi-wall design and construction of the NAC-STC(V) allows cask manufacturing to be performed in the planned country of use thereby increasing industrial capabilities and minimizing the use of foreign currency or credits.

REFERENCES

10CFR71 “Packaging and Transportation of Radioactive Materials”, Part 71, Title 10 of the Code of Federal Regulations, 1995.

IAEA Safety Series No. 6 “Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990)”.

USNRC Certificate of Compliance No. 9235, Revision 0, dated September 30, 1994.

USNRC Approval Letter for NAC-STC For Use at an Independent Spent Fuel Storage Installation, July 17, 1995.

Table 1
Key Design & Operational Characteristics of the NAC-STC and NAC-STC (V)

Designer NAC International
Cask Type Dual-Purpose Storage and Transport

	NAC-STC	NAC-STC (V)
Capacity		
Intact Spent Fuel Assemblies	26 PWR	85 VVER-440
Enrichment (%U^{235})	4.2	3.6 to 4.4
Design Heat Rejection (kW)	22.1	26
Shape	Cylindrical	Cylindrical
Dimensions (mm)		
Overall Length	4834	3903
Overall Diameter	2495	2495
Cavity Length	4191	3243
Cavity Diameter	1803	1803
Wall Thickness	345	345
Inner Lid Thickness	229	229
Outer Lid Thickness	134	134
Bottom Thickness	347	296
Basket Length	4178	3166
Basket Diameter	1798	1798
Weight (metric tons)		
Loaded	105	92
Empty	88	72
Transport	113.4	100
Neutron Shield (mm)		
Side Thickness	140	140
Materials of Construction		
Cask Body	SS/Lead/SS	
Basket	SS/Al with SS/BORAL Tubes	SS/Al with SS/BORAL Tubes
Neutron Shield	GESC NS-4-FR	GESC NS-4-FR
Cavity Atomosphere	He	He
Cavity Pressure (bar)	1.0	1.0
Outside Surface Dose (mSv/hr)	<0.4/midplane	<0.4/midplane

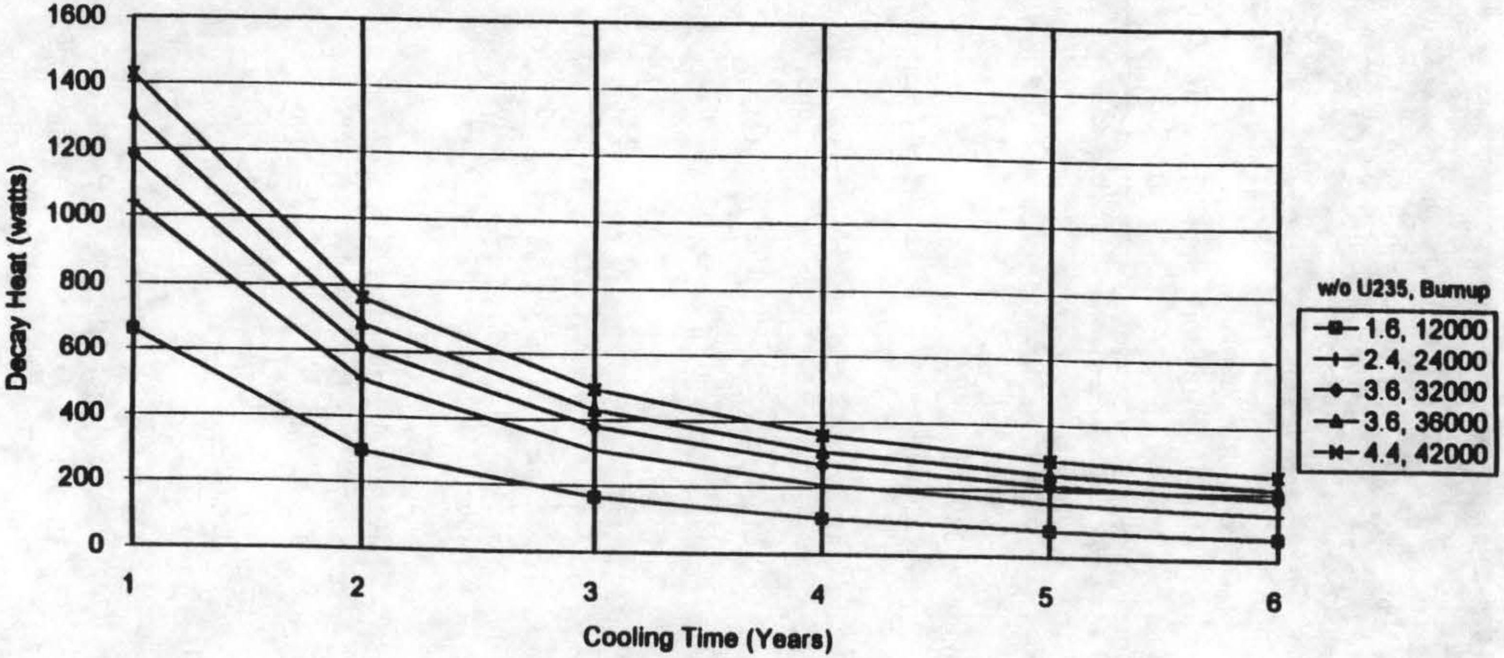

Figure 1
Decay Heat vs. Cooling Time
VVER-440 Fuel Assembly Basis

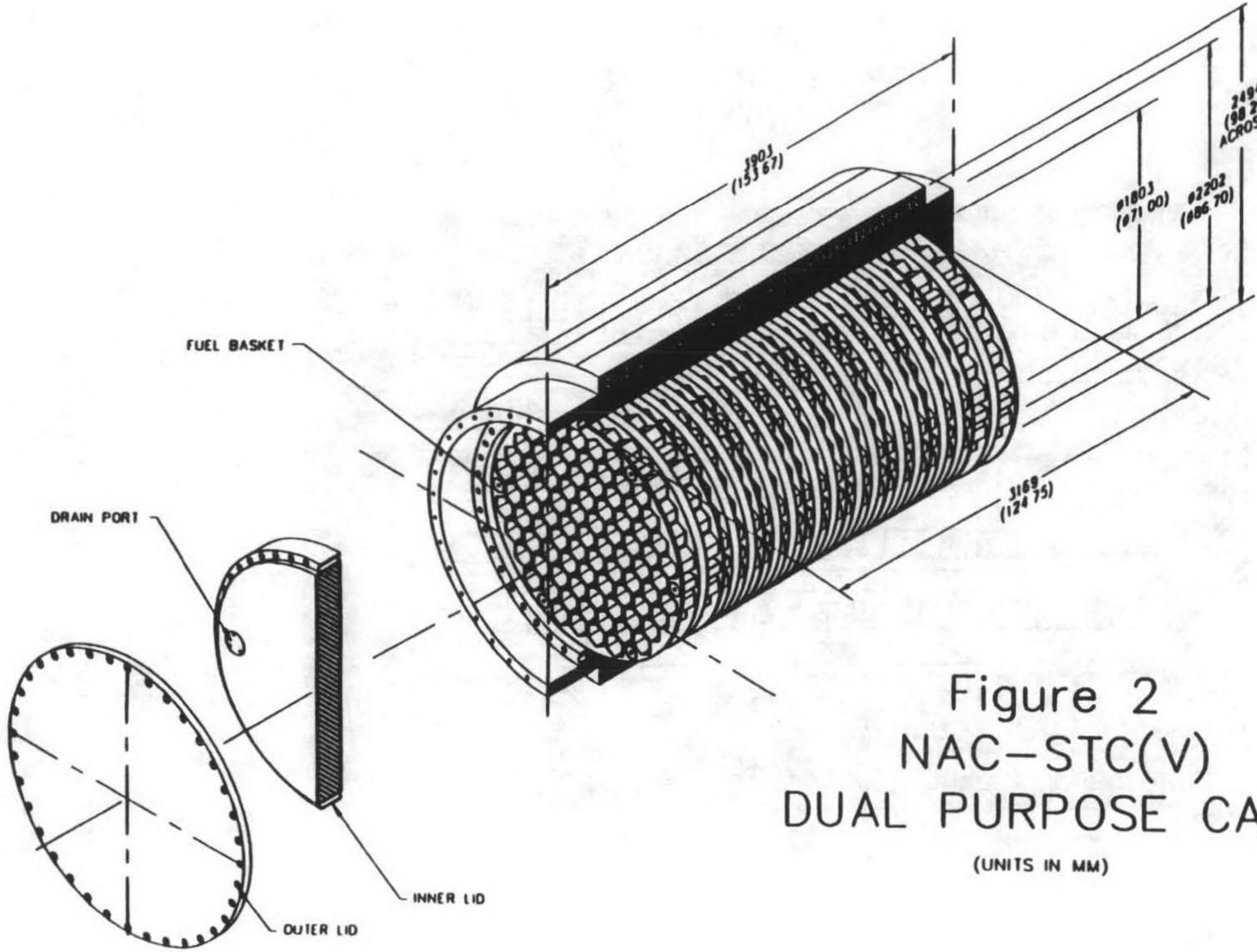

Figure 2
NAC–STC(V)
DUAL PURPOSE CASK
(UNITS IN MM)

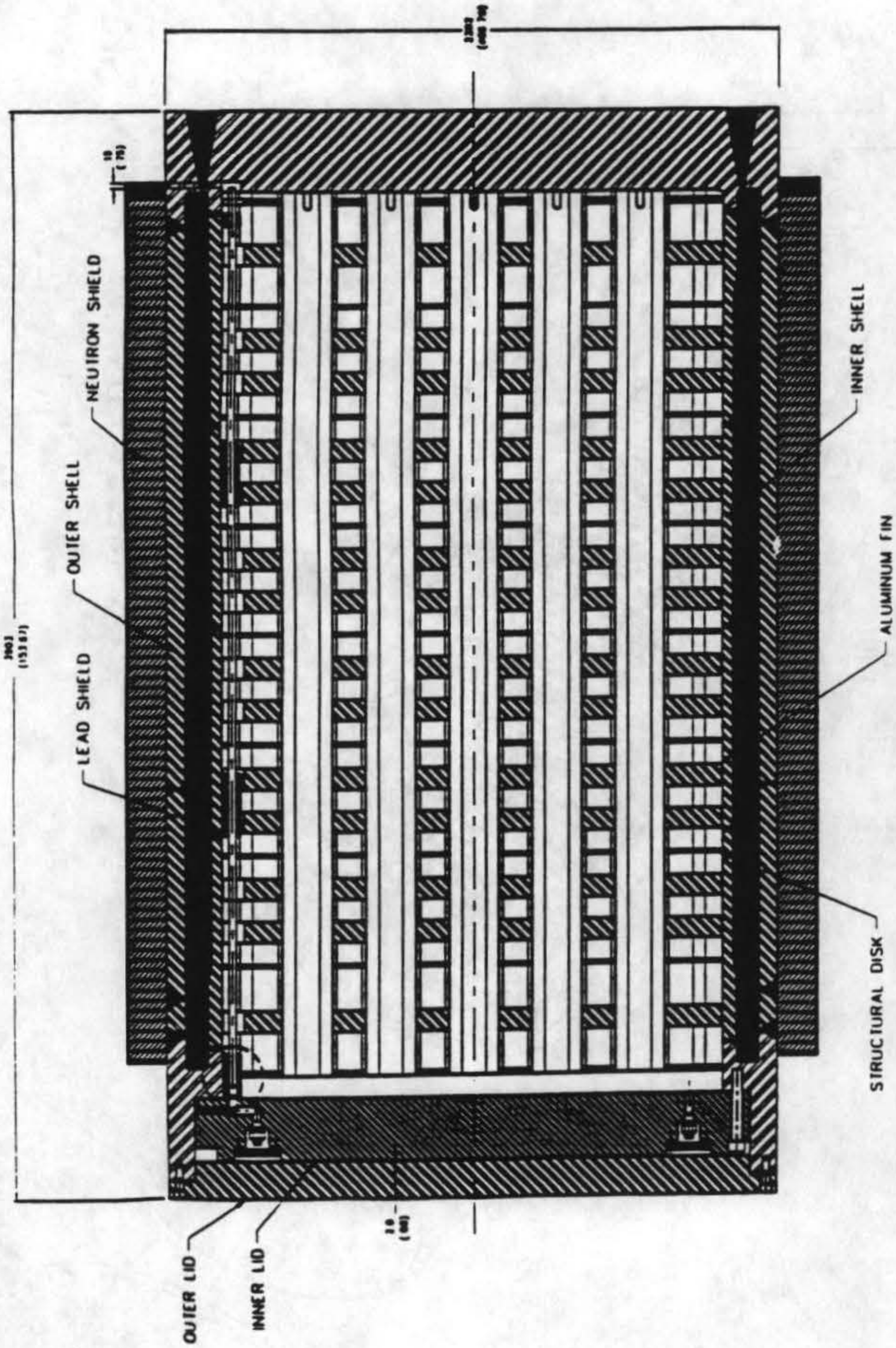

Figure 3
NAC-STC(V) CASK
ASSEMBLY
(UNITS IN MM)