The Evolution of Dry Spent Fuel Storage in the United States

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ABSTRACT

This paper reviews the evolution of Dry Spent Fuel storage technology and application in the United States. Dating back to the legislation signed by Jimmy Carter on April 7th, 1977, to outlaw spent fuel reprocessing, the nations spent fuel pools are gradually becoming filled to capacity. This has necessitated the development of new technologies to store spent fuel in dry casks, predominantly at nuclear power plant sites, awaiting the availability of the federal repository at Yucca Mountain. Site-specific conditions and changes in types of fuel being discharged from reactors have driven a constant evolution of technologies to support this critical need. This paper provides an overview of those changes, which have influenced the evolution of dry storage technology. Focus is provided more towards current technology and cask loading practices, as opposed to those technologies, which are no longer in heavy use. Detailed pictorial material is presented showing the loading sequences of various systems in current use. This paper provides a critical primer on Dry Spent Fuel Storage technology. It provides anyone who is new to dry storage, or who is contemplating initiating dry storage at a nuclear plant site, with useful background and history upon which to build programmatic decisions.

INTRODUCTION

When spent nuclear fuel reprocessing ceased in the United States, utilities began paying into a fund, which was utilized by the USDOE, to establish a repository for spent nuclear fuel. The plan was for a depository to begin accepting spent fuel, starting in late 1998. In 1975, that seemed like a reasonable proposition. Since then the travails of repository development have been well documented, and will not be repeated here. Spent fuel pools, which were originally designed to hold about ten years of fuel discharges from plant operations and refueling outages, suddenly became challenged to see how much fuel they could be expanded to accommodate. Several iterations of reracking of spent fuel pools eventually resulted in the pools “maxing out” with respect to their ability to accept further discharges of spent fuel. Some utility fuel managers forecasted this problem, beginning as soon as the early eighties. This led to commercial development of technology capable of storing fuel, after an initial cooling period of several years in the pool, in cylindrical dry casks set on concrete pads. These pads are known as Independent Spent Fuel Storage Installations (ISFSI’s).

THE EARLY YEARS

PATRAM is an international symposium on the Packaging and Transportation of Radioactive Materials, which is sponsored by the DOE and hosted by the Institute of Nuclear Materials Management (INMM) in cooperation with the International Atomic Energy Association (IAEA). In presentations made during these symposia in the late seventies in Berlin, authors were vilified for the ludicrous idea of taking fuel out of the water and wasting time and energy to develop dry storage technology since the government was to begin taking all spent fuel in 1998. Fortunately for the US nuclear power industry, these prescient scientists were not deterred in their efforts.

The first such system was developed by Ridihalgh, Eggers and Associates (REA). Shown below in Fig. 1 is the first drawing from the patent application number 4,666,659 for "Shipping and storage container for spent nuclear fuel", which was filed on October 23rd, 1983 by Elmer Lusk and John Ridihalgh.

The REA 2023 was designed to hold 52 BWR fuel assemblies and 10 Metric Tons Uranium (MTU), or 24 PWR Fuel assemblies (11.5 MTU). Or, if fuel was consolidated it could accommodate 104 and 48 assemblies and 20 and 23 MTU respectively, hence the name "2023".

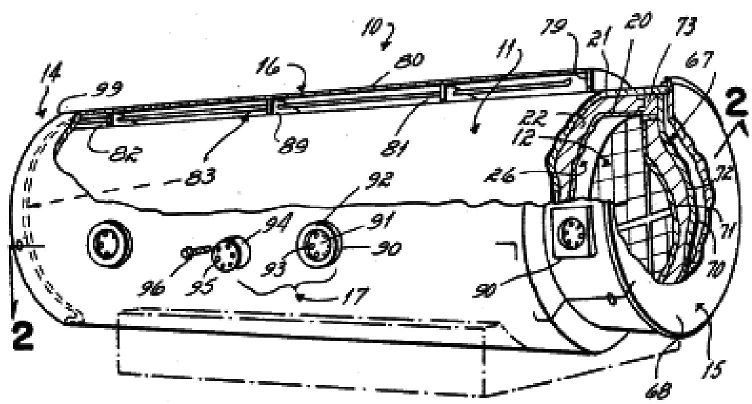

Fig. 1. Drawing from REA patent application for dry storage cask

Fig. 2 shows the first advertisement for the REA 2023, billed as "The first domestic commercial spent fuel dry storage cask completed for the Department of Energy program demonstrating methods to improve on-site utility fuel storage capacity."

Fig. 2. 1983 Advertisement for REA 2023

Fig. 3 shows Elmer Lusk with the first REA 2023.

Fig. 3. Elmer Lusk (left), with REA 2023

THE EIGHTY'S AND NINETY'S

Since the development of the REA 2023 many new storage systems have been developed by designers including Westinghouse, British Nuclear Fuels Limited, Sierra Nuclear, Vectra, GNB, TransNuclear, NAC and Holtec. As time passed through the eighties, utilities who owned older nuclear plants became increasingly concerned that no federal facility would be prepared to accept fuel before their plants lost the capacity in their spent fuel pools to accept discharged fuel. Most plants prefer to maintain the ability to off-load one complete core load of fuel, which is known as full core reserve. The date when a plant loses full core reserve is often referred to as LOFCR date (Loss Of Full Core Reserve). LOFCR is used for planning purposes as to when alternate fuel storage capacity, such as dry storage, must be available to allow the plant to continue to operate.

The New Millennium

There is currently fuel stored in 34 locations in the systems mentioned above. These systems initially were developed for storage only. However, in anticipation of the eventual need to transport stored fuel to a federal repository, most systems put into use today are designed for storage and transport.

Today there are 38 licensed and/or operating ISFSI's in 25 states, with 14 announced plans for new ISFSI's. As of this writing there were 794 loaded casks in the United States.

There are currently only three remaining suppliers of dry spent fuel storage casks, NAC International, Holtec and TransNuclear (TN). The dry storage systems are similar in that they all contain an inner stainless steel canister which contains the fuel, and an overpack cask made of concrete or steel. NAC and Holtec provide vertical cylindrical concrete overpacks while TN offers horizontal rectangular concrete vaults as well as a cylindrical metal vertical cask.

Market share between these three suppliers is about 16% Holtec, 20% NAC and 50% TN, as measured by percentage of loaded casks, with the remaining share split among inactive suppliers. Current purchase decisions are based on a combination of factors including fuel assembly capacity, thermal heat load capacity, fuel burn-up capacity, cost, and loading simplicity to site-specific conditions. TN's horizontal NUHOMS units have garnered the majority of recent competitive awards while NAC is developing it's MAGNASTOR system with extended fuel capacity and Holtec is promoting an in-ground version of its popular HI-STORM vertical concrete cask. Fuel capacity on current systems ranges between 24 and 32 PWR assemblies per cask and from 61-68 BWR assemblies per cask.

Storage Cask Loading

The loading sequence for these systems is as follows: The inner canisters are placed inside a shielded "transfer cask" which is then lowered into the spent fuel pool. The canisters are then loaded with fuel and removed from the pool, with the canister still resident within the transfer cask. The canister is then drained, dried, sealed (via welding or bolting) and filled with an inert gas. Once filled the canister is then transferred into the overpack for placement onto the ISFSI pad.

While there are technical design and licensing differences between each supplier and the available models they offer, there are many operational similarities. For the purpose of basic education, the NAC UMS (Universal Multi-purpose canister System) and it's operational loading sequence, is illustrated below:

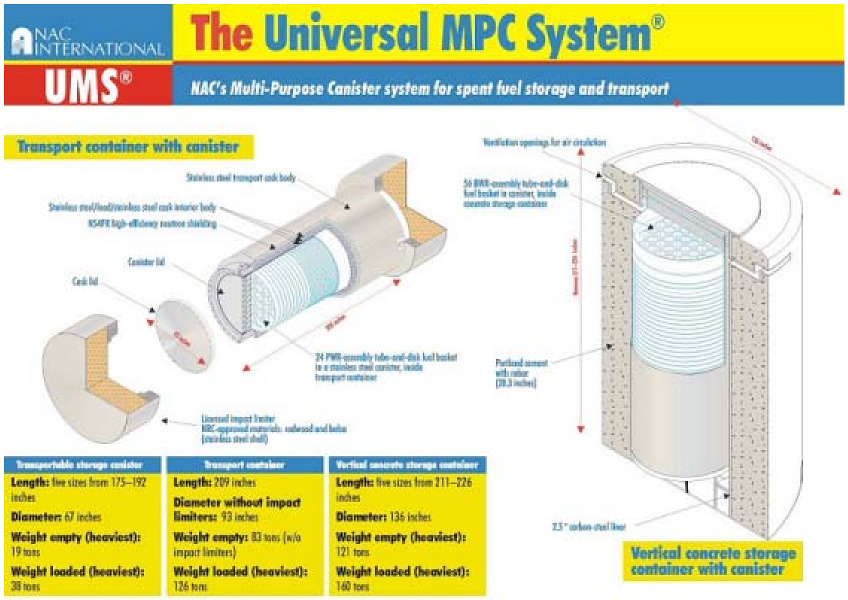

Fig. 4. System overview of NAC UMS

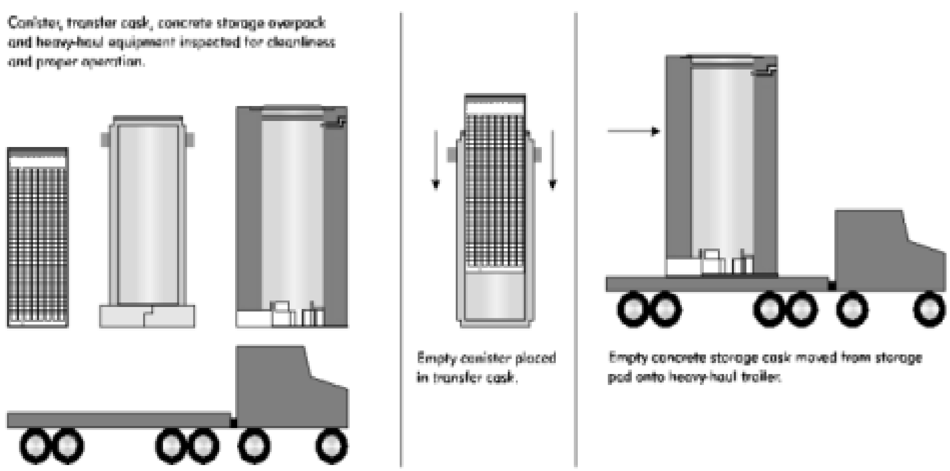

Fig. 5. Equipment inspection and preparation for NAC system

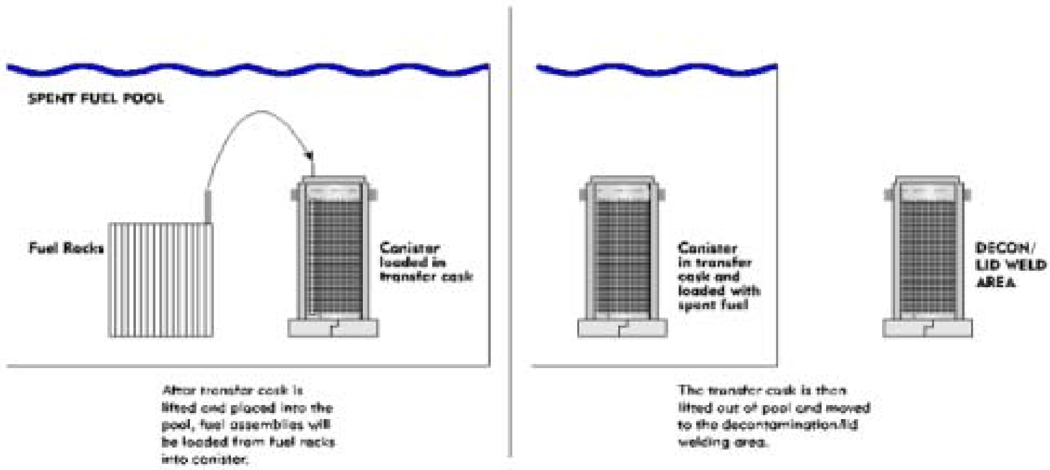

Fig. 6. Fuel loading of NAC system

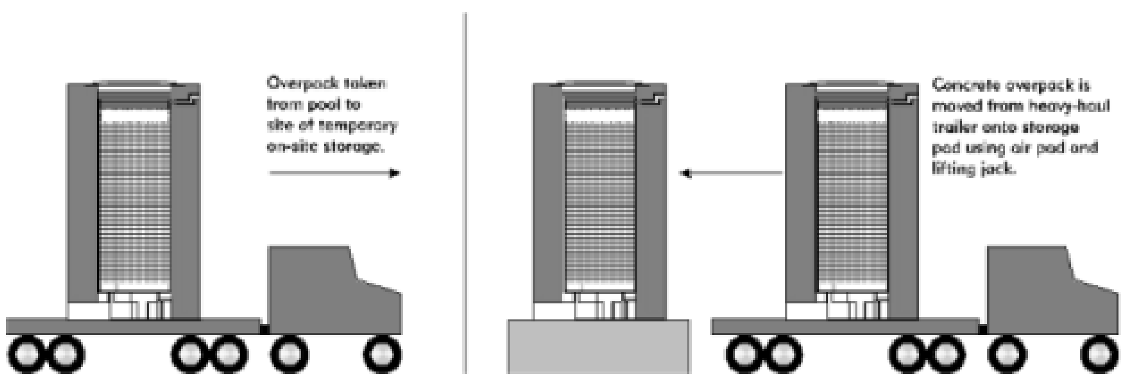

Fig. 7. Cask placement for on-site storage of NAC system

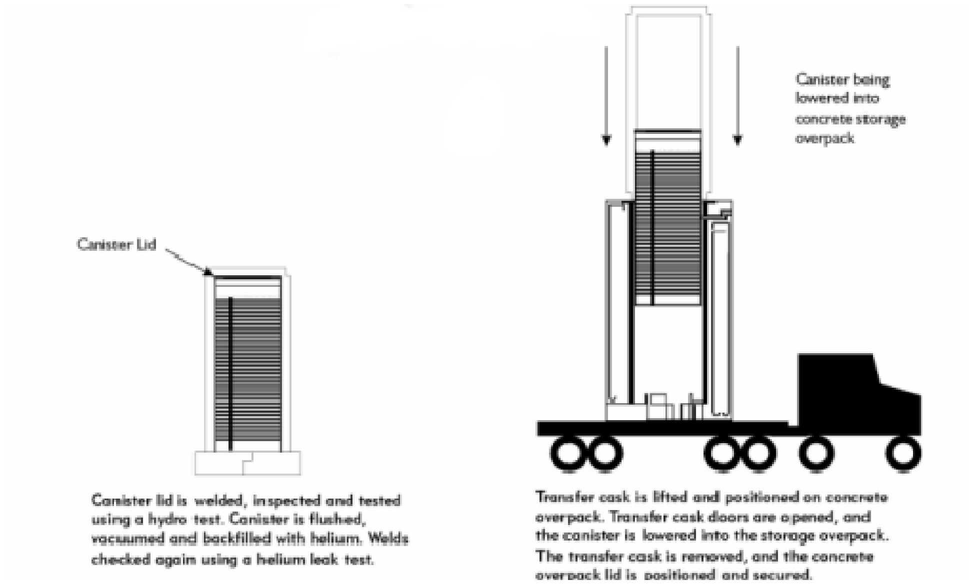

Fig. 8. Canister sealing and transfer of NAC system

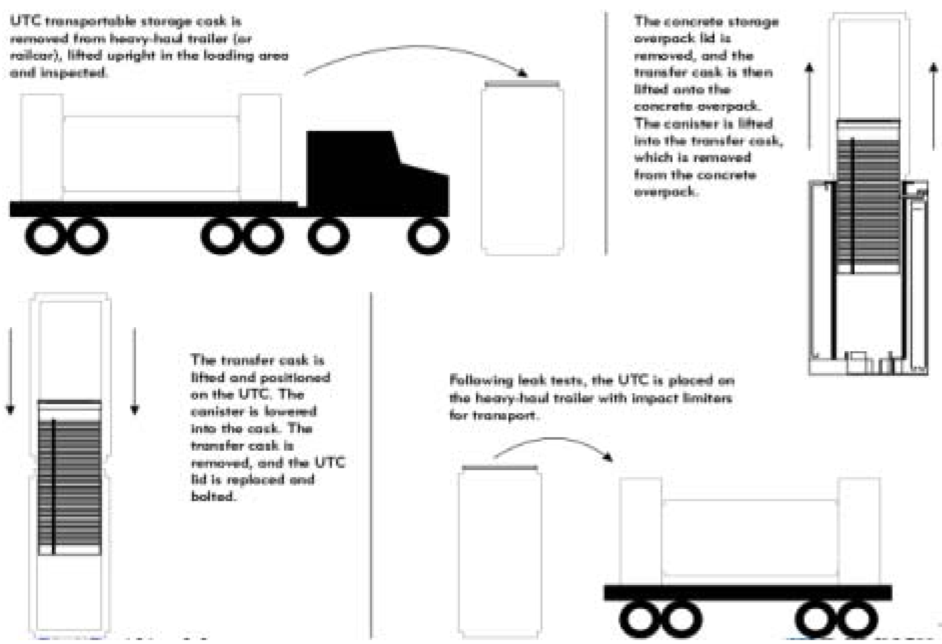

Fig. 9. Transport preparation and loading of NAC system

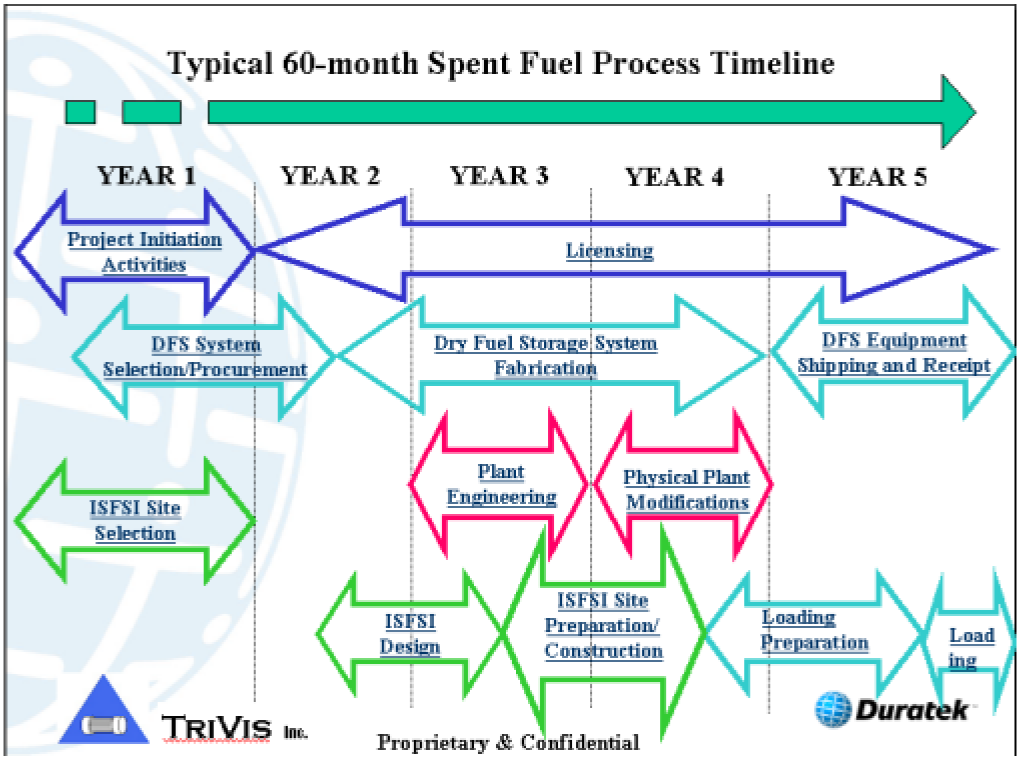

Fig. 10. Typical dry spent fuel utility planning timeline

PLANNING, PREPARING AND IMPLEMENTING DRY SPENT FUEL STORAGE

Once a utility decides to enter into dry fuel storage (DFS), there are numerous time-consuming activities that must be performed. At first glance, compared to operating the plant, DFS activities are often viewed as simple exercises. As a result of thinking "How hard can that be?" many projects start out with inadequate schedules, budgets and staffing. There is an inevitable period of educating the plant organization that this is a long-lead activity that involves QA, operations, security, training, health physics. Between 75 and 150 procedures will be changed and it touches virtually every organization in the plant.

The timeline shown in Fig. 9, gives an approximate schedule overview of the major activities and their relative sequencing.

CONCLUSION

Dry storage of spent nuclear fuel at nuclear plant sites is now a critical temporary (albeit long-term) component in managing spent fuel discharges from US nuclear power plants. Without dry storage many nuclear plants would be forced to discontinue operations due to lack of storage for spent fuel. The evolution of dry storage technology over the past quarter century has resulted in robust systems capable of accommodating increasingly thermal heat loading and burn-up of fuel currently discharged and forecasted to be discharged in the future. Implementation of dry fuel storage flies in the face of long-taught nuclear fuel management practices of keeping it deep under water. It requires substantial financial and organizational resources and an extensive pre-planning timeline. 60 months is typically the minimum time required to develop and implement dry cask storage, from the point when it is decided to engage. Dry storage will be common practice at many plants by the end of the decade. Current industry experience in these areas is relatively minimal and the industry learning curve is steep. Over time, best practices will evolve to permit specialized teams to perform these activities on a routine basis.

ACKNOWLEDGEMENTS

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