EFFECTIVELY MEETING SPENT FUEL STORAGE NEEDS WITH A FAMILY OF DRY STORAGE CASKS

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ABSTRACT

During 1988-89, a number of nuclear utilities have announced their intent of developing supplemental spent fuel storage. These on-site facilities are to be operable by 1991-93. The CASTOR Ductile Cast Iron (DCI) storage casks is a tested and licensed means of meeting this fuel storage need. Since 1986, a total of 14 casks have been sold to the Virginia Power Co. (V.P.). Eight casks are now loaded and in storage at the V.P. Surry Nuclear Station. These casks are directly pool loaded and moved to a storage pad using straight forward handling operations. Once on the pad, there is no further need for cask operation or maintenance with this sealed and passive storage system.

Competitive spent fuel storage systems must be designed to meet the unique aspects of the nuclear plant. Specifically, our studies have shown considerable variations in fuel dimensions and fuel pool crane capacity between plants. To match these needs, General Nuclear Systems, Inc. (GNSI) the U.S. supplier of these casks have developed a family of cask systems. This family system, which is based on four cask body sizes, uses proven designs and licensing precepts. As a result, cask licensing and delivery can be rapidly and predictably accomplished. The casks can be loaded with existing crane capacities, from 25-150T. The casks can be shipped using existing transport networks and readily move within the reactor plant boundaries. Differing fuel configurations, sizes, initial enrichment, cooling periods and burnup conditions can be stored. This flexibility is simply met by the use of different fuel baskets for common fuel cask bodies.

There are other important advantages to the CASTOR family system. Fuel baskets can be designed to accommodate other consolidated fuel canisters or fuel with a "burnup-credit" allowance. It is expected that these improvements in storage technology will be in practice within a few years. Also, the cask bodies are designed and tested for possible use as transport casks. This should permit the utility to eventually ship the fuel off-site to a federal waste repository without the need for additional repackaging.

The use of the DCI technology permits considerable flexibility in cask design. This use of common cask body sizes also improves economics and delivery times. The cost of the DCI body is considerably improved when multiple copies are cast. Utilities can count on receipt of 4-6 licensed casks within a year of cask order.

The entire CASTOR storage system is based on flexibility to best meet the needs of the nuclear plant. This flexibility in fuel types and handling limitations can be met with a family of cask bodies. The resultant benefit is the use of proven and maintenance free technology at a competitive cost.

INTRODUCTION

Increasing numbers of nuclear power plants are looking for technically adequate and cost effective means of providing on-site storage of spent nuclear fuel. This need for storage, starting in the early-to-mid-'90's is due to actual and perceived delays in startup of the government's federal repository. There are several technical options which have been proposed for providing interim on-site storage at the utility. At present, the only fully licensed and operational alternative is the metal dry storage cask. Eight (8) CASTOR ductile iron casks have been loaded and are now in storage at the Virginia Power Surry Station. An additional six CASTOR casks are in fabrication or awaiting loading. Four additional dry storage casks were loaded at the US DOE - Idaho National Engineering Laboratory (INEL). These casks are a part of a combined U.S. Government - industry R & D program. The testing and storage of spent fuel was initiated in 1985 and has been successful in showing the feasibility of metal cask storage.

Suppliers of metal casks have been able to provide casks on a timely basis with NRC approval for spent fuel storage. However, a key utility concern has been minimizing total cost. A prime factor in reducing dry storage cask cost is the volume production of standard design casks. Experience shows that each reactor site has unique requirements due to different fuel types and operating limitations specific to each plant. Attempts by the suppliers of storage casks to meet utility specifications has resulted in their offering a variety of different cask designs with higher cask costs as a resultant.

An attempt has been made to standardize the casks by using a family of designs. General Nuclear Systems, Inc. (GNSI), the developer of the CASTOR, Ductile Cast Iron (DCI) cask is developing such a family, with several basic cask body designs. These fundamental designs can be used to accommodate the total spectrum of utility requirements. This family cask system makes optimum use of the advantages of DCI technology. For example, the casting of a standard body size permits rapid and economic production and can readily accommodate simple dimensional changes. This paper discusses the way that a family of designs can be employed to ensure that all utility technical requirements for spent fuel storage can be met in an economical and flexible manner.

TECHNICAL VARIATIONS IN SPENT FUEL STORAGE

Table one presents the key areas of difference in utility requirements for spent fuel storage and their effect on cask design. The two major factors in meeting the storage requirements are:

- Cask crane lifting limitations
- Spent fuel type and dimensions

The crane rating limits the loaded weight of the cask. The spent fuel dimensions effects the total cask height and the design of the cask fuel basket. Other spent fuel parameters such as initial fuel U-235 enrichment, fuel burnup, and fuel cooling period determine the cask payload (ie. - the number of F/As which maybe stored in the cask).

GNSI assessment of U.S. utility needs resulted in the design of three different cask body sizes, each within a demarcated weight limit. These were the:

FAMILY DESIGNATION	CASK LOADED WT, TONS	FUEL STORAGE, MTU
• CASTOR V/12	5560T	5 6
• CASTOR V/21 AND X/33	115 125T	10 15
• CASTOR LARGE*	180 200T	2530

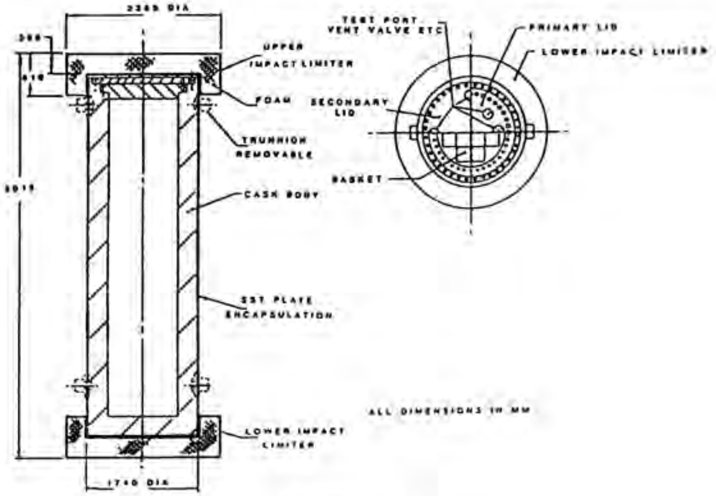
*(Cask is dry loaded with 25-30T fuel transfer cask.)

Each of these casks is discussed in subsequent sections of this paper. In each design within the family, the removable fuel baskets are modified to meet specific spent fuel dimensions and nuclear parameters. Differences in fuel lengths can be accommodated by minor increases in cask body length (easily accomplished with a casting mold) or fuel cavity spacers. The shielding and thermal values for

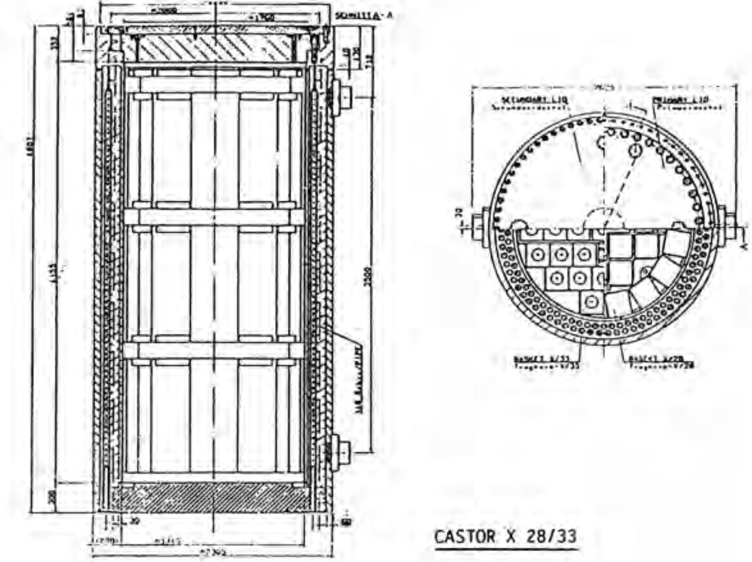
TABLE I

Utility Spent Fuel Storage Parameters

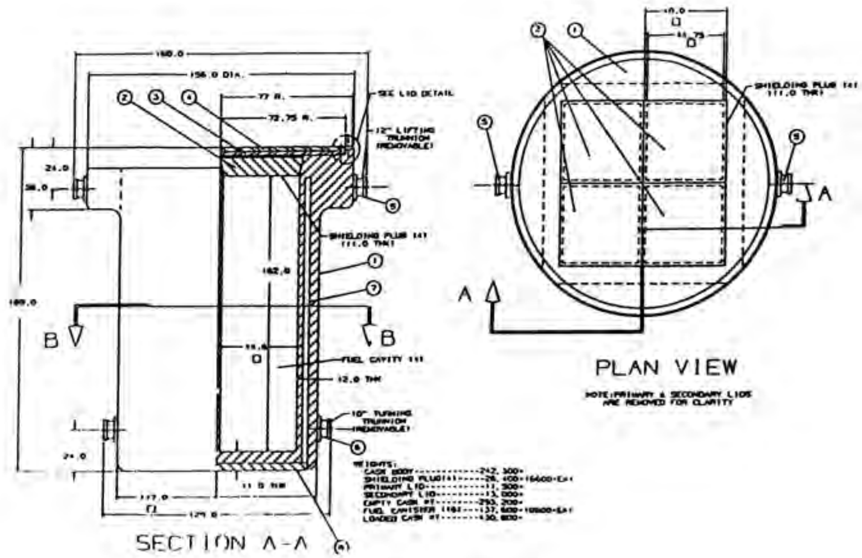
PARAMETER	RANGE	EFFECT ON CASK DESIGN
• Cask Crane Weight Limit	25 - 125T	Cask body weight
• Fuel Cask Minimum Handling Envelope	>8' sq X 15' H (Typically)	Cask body external dimensions
• Fuel Type	PWR, BWR, HTGR	Fuel basket cell size
• Fuel Cross-Section	5.5" sq BWR 7.9-8.55" sq PWR	Fuel basket cell size
• Fuel Length	136" - 206"	Cask body length
• Fuel initial ^{235}U	1.8 - 4.5% Enrichment	Fuel basket cell spacing
• Fuel Burnup	10,000-50,000 MWD/MTU	Cask body thermal & shielding rating
• Fuel cooling period	5 yrs - 10+ yrs	Cask body thermal & shielding rating



CASTOR V/12



CASTOR X 28/33



CASTOR LARGE

CASTOR V/12

- Cask Wt
  - Empty 53.6 T
  - Loaded 61.8 T
- Cask Cavity Dim., Dia, Ht, (in) 44.4", 151.6"
- No. F/A - PWR 12
  - BWR 27

CASTOR X 28/33

- Cask Wt
  - Empty 92.9 T
  - Loaded 116.6 T
- Cask Cavity Dim., Dia, Ht, (in) 68.7", 163.6"
- No. F/A - PWR 28, 33
  - BWR 64, 76

CASTOR LARGE

- Cask Wt
  - Empty 146.6 T
  - Loaded 215.4 T
- Cask Cavity Dim., Dia, Ht, (in) 89.2", 162"
- No. F/A - PWR 64
  - BWR 147

Fig. 1. Key Dimensional Parameters for Each of the Cask Families.

each cask are established for design limiting conditions and meet specified conditions, e.g.

- cask contact dose (max) 100 - 125 mR/hr
- cask thermal rating 15 - 30 KW

These values determine the loading of selected spent fuel assemblies within the cask. Figure one illustrates the key dimensional parameters for each of the cask families.

CASK FAMILY DISCUSSION

General Cask Family Characteristics

Table two presents the design areas common to all casks. These reflect GNSI and their West German partner's (GNS-ESSEN, FRG) experience in fabricating over 80, 50T or larger casks for utility storage requirements using DCI. The design facets such as smooth exterior cask walls, standard fuel cell baskets, etc. are aimed at ensuring maximum operational efficiency at minimum cost. The monolithic cask body structure obtained with casting technology provides considerable structural strength as well as excellent heat transfer and nuclear shielding capabilities.

A summary description of the technical attributes of each cask type in the family of design is presented below.

CASTOR V/12

This 50 - 60T cask has the lightest weight and the lowest capacity. It's application is focused on utilities that have handling limitations imposed by cask crane loading or handling space limitations. When contrasted with the other cask designs, a lower capacity limit of 12 PWR F/A (N ~5.5 MTU) results in an increase in the number of casks required, the number of actual cask loading operations, and the storage pad size for any given quantity of fuel to be stored. However, there is an economic compensation since production of more casks results in economies of production. In addition, the fuel basket design is simpler and less costly.

TABLE II

COMMON DESIGN AREAS

- Monolithic Ductile Cast Iron Body
- Stainless Steel Fuel Basket
- Borated Stainless Steel for Neutron Control
- Smooth, Epoxy Painted Exterior
- Helium Cavity Gas
- Inter-Lid Leak Monitoring System
- Up To 4 (Upper) Lifting Trunnions
- Up To 2 (Lower) Rotating Trunnions
- 1×10^{-7} ATM-CC/SEC (or Lower) Leak Tightness of All Connections
- Double Metal "O" Ring Gasketed Joints

CASTOR V - ISFSI PHOTO

The smaller cask can be used at over 80% of the U.S. reactors. It is ideally suited for eventual use as a rail transport (dual-purpose) cask. The lower cask weight will permit unrestricted movement on the majority of the nations rail lines. For nuclear sites without rail access, heavy haul to a rail spur on public roads can be readily accomplished.

CASTOR V/21 - X/33 CASK

This cask size and weight offers a realistic upper size limit for in-pool loading of spent fuel. The 125T loaded weight limits its application to approximately 45% of the U.S. reactor sites --- assuming no major site modification is made. This series of casks has been licensed and used in the U.S since 1976. Figure 2 is a photograph of the CASTOR V/21 casks with fuel in storage at the Surry Station. This cask design is the most operationally efficient since fewer pool loadings are required.

This cask body has great flexibility in accommodating wide variations in nuclear fuel characteristics. The CASTOR V/21 can be utilized for worst case fuel conditions --- specifically fuel cooling periods of only five years with high-burnup and fuel enrichments of 4.1 percent or higher. The CASTOR X-33 is a higher capacity version of the CASTOR V cask. This design can store 50% more fuel assemblies than the V/21. This capacity increase is dependent on a longer fuel cooling period (typically 10 years or more). In addition, the utility must obtain credit for the reduced reactivity due to burnup of ^{235}U.

CASTOR - LARGE CASK

The CASTOR-LARGE design is aimed at providing an economical "storage-only" cask when fuel pool handling restrictions are severely limited. Up to 4 F/A's are canistered at a time and moved from the pool in a light 25-30T transfer cask. The transfer cask is employed with a shielding bell to dry load the CASTOR-LARGE storage cask. Fuel transfers would be made with the storage cask near the reactor fuel pool to expedite operations. The CASTOR-LARGE cask, when fully loaded and tested, would then be moved to the on-site storage pad.

The transfer cask system could be employed at any U.S. reactor without requiring site modification. The transfer cask systems are a proven and tested technology. Four nuclear waste transfer systems have been developed and efficiently operated in Europe and the U.S. by GNSI/GNS.

There has also been considerable experience in the casting of very large and heavy cask bodies. Cask bodies weighing in excess of 120T have been cast. Larger sizes are possible.

The advantages of employing a very large cask with a fuel transfer system is in the inherent flexibility in meeting a wide variety of conditions. The large storage capacity of this cask requires that the utility only purchase 1-2 casks per year to accommodate all reactor discharge needs. The size of the on-site storage facility is also greatly reduced, more handling operations are required. Typically 16 to 24 fuel

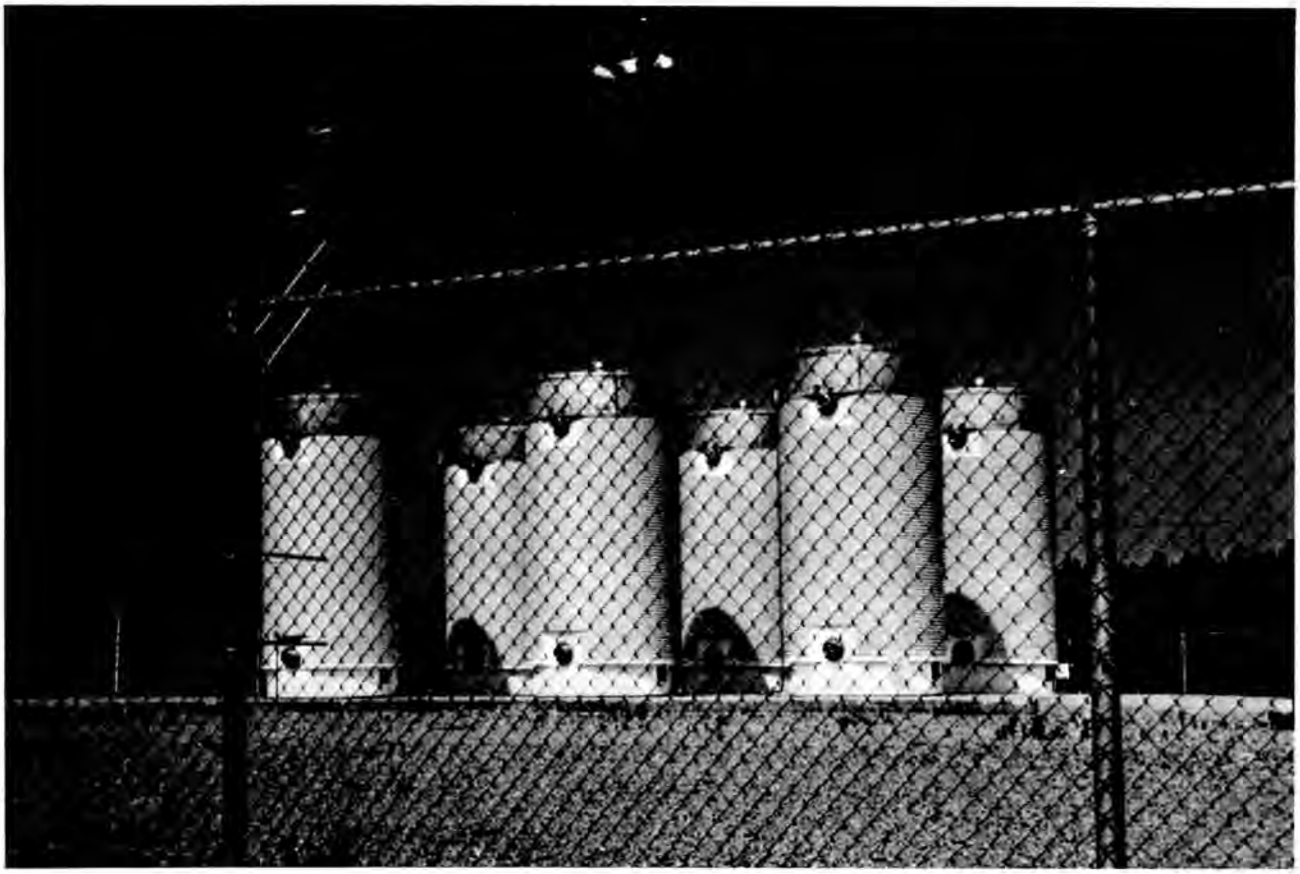


Fig. 2. Six Loaded CASTOR V/21 Casks on Virginia Power Surry Station ISFSI Pad Showing the Security Fencing.

transfers are required to load a storage cask. The fuel transfer operations are greatly simplified by using a

multi-assembly fuel canister and the handling efficiency of the light weight transfer cask. The corresponding reduction in storage cask decontamination reduces the time needed for the final preparation and closure of the storage cask.

SUMMARY AND CONCLUSIONS

This paper has briefly described the CASTOR family of spent fuel casks. The objective of the family design is to ensure that an economical means of metal cask storage is available to meet the requirements of every U.S. nuclear reactor. This is accomplished by the use of standard, NRC approved metal cask bodies with different fuel basket internals (Fig. 2 shows the application of two different baskets for the CASTOR X to accommodate different fuel burnup conditions).

The CASTOR family of designs is based on proven NRC licensing precedents. The construction and operation of these casks has been proven both in the U.S. and worldwide.

Long term, safe storage can be made available in incremental capacity segments to improve utility economics. Rapid production of casks using the DCI technology provides a utility with the cost effective option of purchasing the required number of casks --- only when needed. It also serves as a means of matching utility requirements with that of the DOE programs. This is an approach that will eventually lead to industry standardization.

Recent NRC announcements regarding standardization of licensing approvals for on-site storage (Reference one) will provide further utility flexibility in scheduling and application. Prior NRC approval of cask designs provide confidence that the reactor can meet storage needs with any approved cask design. In concert with this, the CASTOR storage cask series is aimed at economically accommodating different fuel and site conditions. As noted previously, this can be accomplished by using either a different fuel basket --- or a cask body.

In summary, the GNSI objective is to offer the utility both considerable flexibility in meeting their storage needs as well as good economics. This is accomplished by offering a maximum of three cask bodies to meet all situations. This permits the economical production of the most costly portion of the fuel storage system (the cask body) on a volume basis. Since the cask body has previous NRC approval, the utility can confidently plan for any modifications to their on-site storage

REFERENCES

1. Nuclear Waste News - January 12, 1989, page 10.