SPENT FUEL STORAGE CASKS:
A COMMERCIAL REALITY IN 1986

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ABSTRACT

The storage of spent fuel in metal casks has been studied as a solution to the high level waste problems of U.S. utilities. Recently on-site storage casks have emerged from the concept stages into a proven reality. After a period of considerable study, followed by testing and regulatory licensing, the first utility Independent Spent Fuel Storage Installation (ISFSI) will become operational in 1986. This facility, now nearing completion, is located at the Virginia Power-Surry Nuclear Station. The first casks to be used are the GNS model CASTOR V/21. Virginia Power has purchased five of these NRC licensed CASTOR casks to support the first 1-2 years of interim storage.

Metal storage cask technology offers a proven and practical solution to concerns about shortfalls in storage capacity. These casks would be ordered on an as-needed basis which can be shown to be cost effective. Continuing research and testing by DOE is providing a firm technology basis to dry storage in casks. Meanwhile, the entrance of other equipment suppliers into this area and the approval of cask designs by the NRC is a sign of commercial reality. The continuing development of the storage cask option is important to the nuclear industry. These casks can be employed as needed interim spent fuel storage or as insurance against programmatic delays in the opening of a national waste facility.

INTRODUCTION

A number of U.S. nuclear utilities can foresee spent fuel storage problems in the next 5-10 years. These problems will occur when the storage capacity of their fuel pools are exceeded and no other solutions are available. If the short fall occurs in the 1990's, plans should be made for on-site storage until the federal waste storage facility is opened. As federal waste programs seem to be experiencing delays, these alternative solutions are becoming important to all operating nuclear plants.

The on-site storage of spent fuel using large metal casks has been evaluated in recent years, among other storage options. The metal storage cask concept has several attractive advantages. Large metal casks offer storage on an "as-needed" basis. Safe storage for up to 50 years is possible. The facility requirements for extended storage of the cask are not complex and the maintenance and surveillance needed during the storage period are minimal.

Until recently, the storage cask was unproven in the U.S. At this writing, the metal storage cask is now a tested and licensed technology. The purpose of this paper is to present recent developments which are proving this technology. Particular emphasis is focused on the CASTOR V cask. The CASTOR cask series are the first to be licensed in the U.S. for this application. Its application at the Virginia Power ISFSI is evidence of the emergence of this technology in the U.S. These casks were developed in Germany by Gesellschaft für Nuklear Services (GNS) and have been widely used in Europe. They are now commercially offered in the U.S. by General Nuclear Systems, Inc. (GNSI), a joint venture of Chem-Nuclear Systems, Inc. and GNS. As part of continuing U.S. development, the first CASTOR V was tested in 1985 under a joint DOE/utility program. Operating tests with nuclear fuel were independently run by DOE contractors at the Idaho National Engineering Laboratory (INEL). Following this, Virginia Power has ordered five CASTOR V casks for the initial operation of the Surry Station ISFSI facility.

Currently, considerable effort is being expended by GNSI to extend the application of the CASTOR casks for different types fuel assemblies and licensing under 10CFR71 for off-site transportation. The U.S. licensing of these casks for both shipping and storage will increase the operational flexibility and utility of this equipment. This flexibility with the "as needed" basis for purchase makes the CASTOR cask the most economical means of retrievable storage of spent nuclear fuel.

CASTOR-METAL CASK TECHNOLOGY

The CASTOR (Cast Iron for Storage and Transportation) cask employs a ductile iron casting for the purposes of containment and shielding of nuclear fuel (see Figure 1). The casting technology insures a uniform material composition which results in a high integrity containment vessel. This vessel can be fabricated into a variety of sizes and shapes to best accommodate the nuclear fuel characteristics. The casting process is efficient since no welding or complicated manufacturing operations are needed. The primary finishing techniques are machining of the casting surfaces and nickel plating of the interior cavity. Two forged stainless steel lids with multiple gasketed surfaces are bolted to the cask to ensure the containment of the nuclear materials. Typical cask wall thicknesses for nuclear fuel are 13 1/2 to 15 inches. At present, CASTOR casks have been constructed weighing from 80 to 120 tons.

The CASTOR technology represents an evolutionary growth in the use of ductile iron for handling nuclear material. To date, over two thousand ductile cast iron casks have been fabricated. They have been cast in a variety of wall thicknesses and sizes. Most have been used for shipment of intermediate level nuclear waste to European deep mines for permanent storage. CASTOR casks have also received European approval for high level waste (spent fuel) storage and transport. The casting technology has evolved to a point where the material properties can be standardized within a narrow range. The properties, including the material strength and fracture toughness are excellent.

The technology is efficient and rapid manufacturing is possible. As an example, the first cask was delivered to the United States only six months after being ordered. The use of nondestructive techniques as a quality assurance measure to detect small casting flaws is precise. Hence, assurance of a flaw-free casting is guaranteed.

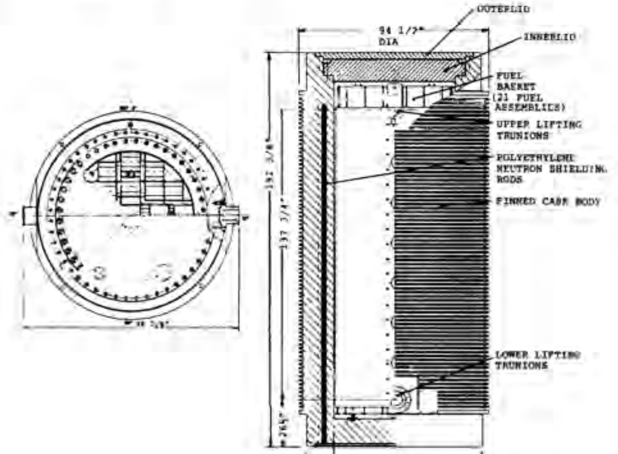

Fig. 1. CASTOR V Cask Cross-Section

The ductile iron material is not only an excellent structural material, but is also used for integral nuclear shielding. Ductile iron serves as both the gamma and neutron shielding in the monolithic structure. The spheroidal graphite within the iron enhances the neutron shielding capability. Also, axial bore holes are drilled in the cask wall and filled with polyethylene rods to augment the neutron shielding. The innovative use of the ductile iron and polyethylene rods for neutron shielding is technically advantageous compared to other fuel casks designs. In most fuel casks, water blankets or solid neutron shields are placed at the cask exterior. These external neutron shields act as thermal insulators and are vulnerable during postulated hypothetical accidents. Also, certain operating problems (e.g. - thermal expansion, freezing protection, decontamination, etc.) must be addressed. These problems are eliminated with the CASTOR cask integral neutron shielding.

The patented lid closure and leak detection system employed with CASTOR casks insures safe storage for an extended period of time. The innovative sealing and leak detection system ensures that the cask cavity is positively sealed for its storage lifetime. The annular cavity formed between the two closure lids is pressurized with six atmospheres of helium. A continuously operating leak detection system monitors for leakage from this annulus. This leak detection system provides positive on-line insurance of tightness. Also, the multiple metal and elastomer gaskets on each closure, have proven reliable under extended storage conditions.

Modifications in the designs of the CASTOR casks can be made to readily accommodate different fuel conditions such as different fuel cooling periods. The CASTOR IC which contains 16 BWR assemblies accommodates one year cooled fuel. The CASTOR V design, which contains a minimum of 21 PWR fuel assemblies, accommodates 5 year cooled fuel. Optimization of a fuel cask must evaluate the effect of the fuel nuclear source strength on shielding requirements as well as the fuel size. These are used to determine the cask wall thickness, size, and weight. Since reactor cranes and spaces are limited, it is necessary to specify a cask weight limit and envelope size which further defines the number of fuel assemblies stored in the cask. Most of the remaining design effort focuses on limiting nuclear criticality and fuel rod temperatures to currently accepted limits (developed in DOE R & D programs). A key criterion is to limit peak fuel rod temperatures to below 380°C in order to maintain fuel integrity. Extensive testing at Idaho has shown that the maximum fuel rod temperatures in the CASTOR V stays below this. The thermal testing at Idaho actually went significantly beyond design heat load conditions. Analytical thermal and shielding models compared closely with the experimental results.

All other aspects of the design and handling of the CASTOR cask series is comparable to that commonly utilized for spent fuel transport casks. The CASTOR handling and loading procedures have been developed to improve upon their use at reactors. Procedures for off-site transport or for eventual use at a waste repository have also been developed. After loading the cask in the reactor pool, the cask is moved to a storage pad. On-site storage with nuclear fuel for up to 50 years is possible. After the cask is loaded, no further examination of the fuel is needed. Only routine surveillance of the closed cask is required during the storage period.

The development of the CASTOR technology in the U.S. is continuing. The CASTOR V model is the baseline design for expected use and meets most U.S. reactor facility requirements. Sufficient testing and analysis has been performed on the CASTOR V under storage conditions to validate its safety and practicality. Continued developments to obtain transport licensing in the U.S. is envisioned for the near future. The transportation licensing environment under 10CFR71 is generally very demanding since potential accident environments are severe. Rigorous proof of the CASTOR structural integrity under these conditions is needed by U.S. regulatory authorities. As noted earlier, the CASTOR casks have been extensively used for transport in Europe under international regulations and authority. Hence, the U.S.transportation qualification will focus on material testing and standardization programs. This effort is now underway, with cask drop testing and additional material qualification planned for 1986 in Germany.

CURRENT TRENDS IN DRY STORAGE IN THE U.S.

Since the demise of U.S. commercial reprocessing in 1976, the nuclear industry has been forced to evaluate techniques to accommodate the storage of spent fuel. The most immediate option is the reracking of the utility fuel pool. When this option is exhausted, some utilities may tranship fuel to other reactor pools within their system. Another utility option is to rely solely on federal solutions, as defined in the National Nuclear Waste Policy Act (NWPA).

The (NWPA) was enacted by Congress in 1982 to provide for the ultimate disposition of high level waste. Time tables have been developed for federal title to spent fuel by 1998. However, federal waste facilities are encountering continuing delays. Later dates are definitely possible in view of the large number of institutional problems. Even then, studies show that there are utilities with pressing near term storage problems who need backup solutions. For these utilities, two alternatives are fuel rod consolidation and storage casks. (Rod consolidation is a disassembly technique to further compact the fuel bundle).

Until recently there was little other than studies available to define the practicality of these alternative storage solutions. In 1985-86, considerable "real world" advances have been made with one option - metal storage casks. Advances were seen in the following areas of participation:

- o <u>Equipment Suppliers</u> - Several fabricators have committed to enter this market. This committment has included preparation of detailed designs and licensing documents. Submittals to regulatory authorities for licensing and committments for the fabrication of casks under fixed commercial terms and conditions have been made.

- o <u>Department of Energy (DOE)</u> - The DOE has funded various applied research studies on the effect of dry storage conditions on fuel integrity. They are now testing metal casks under actual operating conditions. Much of this effort is either in progress or has been completed.

- o <u>Nuclear Regulatory Commission</u> - The NRC has evaluated both dry storage casks and ISFSI's. Two CASTOR dry storage casks (CASTOR IC and CASTOR V/21) have received NRC approval for use by utilities in storing fuel. Other cask designs are under review for storage approval per 10CFR72. The approval of the Virginia Power ISFSI is expected in 1986.

- o <u>Utilities</u> - Virginia Power has pursued an ISFSI. They have procured five CASTOR casks to be used in the initial operation of this facility. Also, other utilities have shown considerable interest in cask storage. Obviously, acceptance by utilities is key to the expected wide spread usage of this technology.

METAL CASK ISFSI DESIGN AND OPERATION

The Virginia Power-Surry ISFSI is a pioneering facility which establishes the licensing and operational constraints for storage cask technology. The economics of the facility and casks serve as a baseline for studies and determinations by other utilities. The Surry IFSFI was conceived by Virginia Power in the early 1980's, when it was realized that this Station would be one of the first to experience spent fuel storage problems. They had previously reracked their pools. They had developed a program for transhipment of spent fuel from Surry to their North Anna Plant. This transhipment, while technically practical, was temporarily deferred. Rod consolidation was also considered, but has not been employed to date. The go-ahead decision for a dry cask storage facility was made in 1982-83. This decision was made in conjunction with a joint DOE/Virginia Power demonstration program of dry storage in metal casks. The design of this facility was developed by Bechtel Power Corp., and licensing started in 1982. Construction was initiated in 1985 and the facility should be completed and in operation by late spring of 1986.

The Surry ISFSI facility consists of a secure and lighted fenced enclosure with concrete storage pads. The facility is within the Surry station boundaries and is located approximately 3/4 of a mile from the reactor plant. There are three engineered concrete storage pads, each approximately 32 feet wide by 200 feet long. There is space for about 30 casks on each pad.

The casks will be moved from the reactor building to the ISFSI along plant roads using a special multi axle, rubber tired transporter. The casks will be positioned and lowered on the pad and spaced about 16 feet apart. The cask leak detection system will be connected to a central monitoring station. This system operates continuously and is automatically monitored. No further contact inspection or maintenance of the cask is expected. Handling procedures for the loading of the cask and the movements within the Surry Station have been developed.

The five additional CASTOR V/21 casks ordered by Virginia Power will be delivered directly to the Surry Site for loading and fuel storage in 1986. These casks will store a total of 105 fuel assemblies (approximately 50 MTU). Three to four per year additional storage casks will be needed per year of ISFSI operation. We feel the costs associated with handling and storage of the cask will be small.

FUTURE DEVELOPMENTS IN METAL CASK STORAGE

Joint utility/governmental programs are continuing at INEL and other DOE contractor facilities. These programs are evaluating and testing metal storage casks as well as other advanced storage techniques. To date, we feel that experience and trends point to the use of the metal cask as the leading means for interim spent fuel storage. The DOE R & D programs are aimed at firmly establishing dry storage limits which ensure fuel integrity. Fuel integrity is assured by limiting upper fuel rod temperatures and the use of inert filler gases for the storage environment. This research is valuable and is continuing. The comparison of temperatures predicted by computerized heat transfer models with measured temperatures is continuing with various casks and fuel configurations. The tests show the effect of basket design, cask orientation, and inert filler gas on fuel rod and cask component temperatures. Tests with cask storage of consolidated fuel is planned for 1987.

At present, at least five storage cask TSAR's have been submitted to the NRC. In addition, other equipment vendors have announced their intent to develop new cask designs. This provides evidence of the industry conviction that the metal cask storage is a commercially viable business. GNSI work on the CASTOR cask and its adaption to the U.S. is focused in three broad directions. We expect that the development programs at other suppliers will address all or some of these areas since they are key to the continuing growth of this technology. These include:

- o Adaptation to other fuel types
- o Transportation licensing
- o Integration with other advanced storage techniques

The CASTOR V/21 has specifically been adapted for PWR fuel, since this fuel type holds most of the current U.S. market share. PWR fuel is technically more limiting than BWR fuel due to higher source strength and initial enrichment. A design for CASTOR cask storing BWR fuel has been developed. Casks for other types of high level nuclear waste are being examined. To accommodate other fuel types, the changes to the cask body are relatively small and follow closely the existing CASTOR V/21 design. Consideration of fuel cooling periods for greater than five years, as well as advanced fuel basket designs will lead to the storage of more fuel assemblies in each cask. These are expected to be evolutionary changes to the CASTOR V design. The benefit of increased cask capacity will be improved economics and reduced operational costs.

Utilization of the CASTOR cask for transportation offers both economic and operational benefits. The cask can be stored for extended periods awaiting eventual shipment to a governmental waste facility. The "leak-tight" condition of the fuel cavity avoids the necessity of removing the fuel for inspection or reloading to another cask. Since the utility already owns the cask, cost credits associated with the transport to a federal facility and temporary storage at that facility should occrue to the utilities account. At present, provisions for utility cask credits are not covered in the NWPA legislation. However, since the use of this equipment has positive benefits to both the federal government and utility programs, there is a possibility of enacting changes as large quantities of dual-purpose casks are purchased. As noted previously, the CASTOR technology has been successfully utilized for transport in Europe. The validation required for U.S. usage is acceptance of the ductile iron material. Ongoing discussions with the U.S. NRC are resolving the extent and type of testing needed for this material. This costly effort is now being pursued to insure that the CASTOR cask can be licensed in the U.S. for transportation.

Developing new fuel baskets to accommodate rod consolidation is a long range goal. Rod consolidation will probably be used at some reactors. More importantly, the federal government plans to consolidate fuel at a federal waste facility. There are several ways that consolidated fuel can be effectively loaded into metal storage casks to increase storage effectiveness. Estimates show that the capacity of a dry storage cask can be increased by 70-100% depending on the cask cavity design and rod consolidation effectiveness. We are examining these effects on current designs with the aim of eventually combining consolidated fuel with metal cask storage.

There are a variety of other advanced techniques being considered on a long range basis by both GNSI and others. One concept is the use of a dry transfer cask with a large storage cask (see Fig. 2. This eliminates pool loading of a large cask. Hence, crane and building size limitations are avoided. This concept may simplify handling operations at some plants. It may open other plants to economical cask storage where plant limits could preclude usage.

CONCLUSIONS

We feel that the events of the last year clearly indicate that the metal cask is a practical means for interim spent fuel storage. The economic predictability, handling conveniences, and licensing experience offered are of considerable importance. To date, of all advanced fuel storage options, only the licensing, testing and actual field operations with metal casks has been verified. The testing of storage casks, in an inert gas atmosphere such as helium and nitrogen, provides a basis to insure long term fuel integrity. The thermal testing has shown that the cask fuel rod temperatures are sufficiently low to preclude any conceivable type of fuel damage mechanism. Also, proven analytical models of fuel rod temperatures can be used to verify the acceptability of a new cask or basket design.

From a commercial standpoint, dry casks can be purchased from several vendors. Costs and delivery schedules can be quoted with acceptable confidence. Utilities can evaluate the actual costs associated with developing an ISFSI and realistic schedules can be developed. Further improvements in economics are expected as additional casks are ordered and used.

We feel that this technique will become a first line alternative for a number of utilities who are giving serious consideration or require on-site spent fuel storage. Recent state actions where states such as Tennessee have rejected federal initiatives for even interim storage, make it incumbent on utilities to have a proven back-up solution. The metal storage cask-utility ISFSI is such a solution. A prudent policy for many utilities would be to design and to file a license application under 10CFR72 for a storage cask ISFSI. The approved facility would serve as insurance for future interim storage needs. The costs would be comparatively reasonable and would minimize schedule concerns if construction of an ISFSI is eventually needed to meet utility requirements.

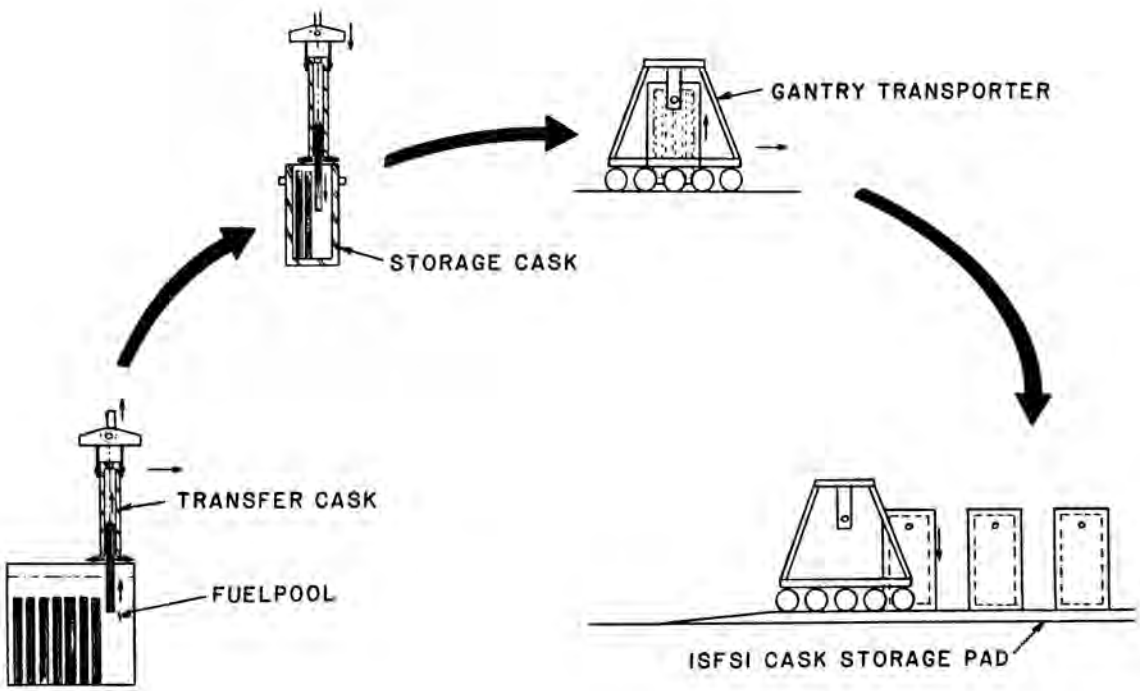

Fig. 2. Dry Fuel Loading Using Transfer Cask.