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DRY CASK STORAGE AND COMPARATIVE RISKS

This chapter addresses the second and third charges of the committee's statement of task:

- The safety and security advantages, if any, of dry cask storage¹ versus wet pool storage at reactor sites; and
- Potential safety and security advantages, if any, of dry cask storage using various single-, dual-, or multipurpose cask designs.

The second charge calls for a comparative analysis of dry cask storage versus pool storage, whereas the third charge focuses exclusively on dry casks. The committee will address the third charge first to provide the basis for the comparative analysis.

By the late 1970s, the need for alternatives to spent fuel pool storage was becoming obvious to both commercial nuclear power plant operators and the Nuclear Regulatory Commission. The U.S. government made a policy decision at that time not to support commercial reprocessing of spent nuclear fuel (see Appendix D). At the same time, efforts to open an underground repository for permanent disposal of commercial spent fuel were proving to be more difficult and time consuming than originally anticipated.² Commercial nuclear power plant operators had no place to ship their growing inventories of spent fuel and were running out of pool storage space.

Dry cask storage was developed to meet the need for expanded onsite storage of spent fuel at commercial nuclear power plants. The first dry cask storage facility in the United States was opened in 1986 at the Surry Nuclear Power Plant in Virginia. Such facilities are now in operation at 28 operating and decommissioned nuclear power plants. In 2000, the nuclear power industry projected that up to three or four plants per year would run out of needed storage space in their pools without additional interim storage capacity.

This chapter is organized into the following sections:

- Background on dry cask storage.
- Evaluation of potential risks of dry cask storage.
- Potential advantages of dry storage over wet storage.
- Findings and recommendations.

¹ This storage system is referred to as "dry" because the fuel is stored out of water.

² The Nuclear Waste Policy Act of 1982 and the Amendments Act of 1987 laid out a process for identifying a site for a geologic repository. That repository was to be opened and operating by the end of 1998. The federal government now hopes to open a repository at Yucca Mountain, which is located in southwestern Nevada, by the end of 2010.

4.1 BACKGROUND ON DRY CASK STORAGE

The storage of spent fuel in dry casks has the same three primary objectives as pool storage (Chapter 3):

- Cool the fuel to prevent heat-up to high temperatures from radioactive decay.
- Shield workers and the public from the radiation emitted by radioactive decay in the spent fuel and provide a barrier for any releases of radioactivity.
- Prevent criticality accidents.

Dry casks are designed to achieve the first two of these objectives without the use of water or mechanical systems. Fuel cooling is passive: That is, it relies upon a combination of heat conduction through solid materials and natural convection/thermal radiation through air to move decay heat from the spent fuel into the ambient environment. Radiation shielding is provided by the cask materials: Typically, concrete, lead, and steel are used to shield gamma radiation, and polyethylene, concrete, and boron-impregnated metals or resins are used to shield neutrons. Criticality control is provided by a lattice structure, referred to as a *basket*, which holds the spent fuel assemblies within individual compartments in the cask (FIGURE 4.1). These maintain the fuel in a fixed geometry, and the basket may contain boron-doped metals to absorb neutrons.³

Passive cooling and radiation shielding are possible because these casks are designed to store only older spent fuel. This fuel has much lower decay heat than freshly discharged spent fuel as well as smaller inventories of radionuclides.

The industry sometimes refers to these casks using the following terms:

- Single-, dual-, and multi-purpose casks.
- Bare-fuel and canister-based casks.

The terms in the first bullet indicate the application for which the casks are intended to be used. Single-purpose cask systems are licensed⁴ only to store spent fuel. Dual-purpose casks are licensed for both storage and transportation. Multi-purpose casks are intended for storage, transportation, and disposal in a geologic repository. No true multi-purpose casks exist in the United States, or in any other country for that matter, because specifications for acceptable containers for geologic disposal have yet to be finalized by the Department of Energy. Current plans for Yucca Mountain do not contemplate the use of multipurpose casks.

Nevertheless, some cask vendors still refer to their casks as “multi-purpose.” These are at best dual-purpose casks, however, because they have been licensed only for storage and transport. **Because true multi-purpose casks do not now exist and are not likely to exist in the future, the committee did not consider them further in this study.**

³ Criticality control is less of an issue in dry casks because there is no water moderator present after the cask is sealed and drained.

⁴ Authority for licensing dry cask storage rests with the Nuclear Regulatory Commission.

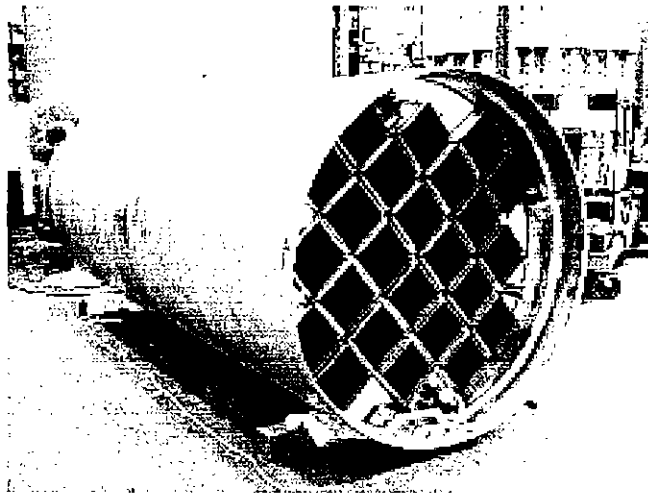


FIGURE 4.1 Photo of NUHOMS canister showing the internal basket for holding the spent fuel assemblies in a fixed geometry. This canister is shown for illustrative purposes only. SOURCE: Transnuclear, Inc.

The terms in the second bullet indicate how spent fuel is loaded into the casks. In bare-fuel⁵ casks, spent fuel assemblies are placed directly into a basket that is integrated into the cask itself (see FIGURE 4.3B). The cask has a bolted lid closure for sealing. In canister-based casks, spent fuel assemblies are loaded into baskets integrated into a thin-wall (typically ½-inch [1.3-centimeter] thick) steel cylinder, referred to as a *canister* (see FIGURE 4.1 and 4.3A). The canister is sealed with a welded lid. The canister can be stored or transported if it is placed within a suitable over-pack. This over-pack is closed with a bolted lid.

Bare-fuel and canister-based systems are sometimes referred to as “thick-walled” and “thin-walled” casks, respectively, by some cask vendors. This designation is not strictly correct because the over-packs in canister-based systems have thick walls. The only thin-walled component is the canister, which is designed to be stored or transported within the over-pack.

The designation of a cask as single- or dual-purpose often has less to do with its design and more to do with licensing decisions. Indeed, bare-fuel and canister-based casks can be licensed for either single- or dual-purpose. Consequently, one should not expect the performance of a cask in accidents or terrorist attacks to depend on its designation as single- or dual-purpose. Rather, performance will depend on the type of attack and construction of the cask. For the purposes of discussion in this chapter, therefore, the committee will use the designations “bare-fuel” and “canister-based” rather than single- or dual-purpose when referring to various cask designs.

All bare-fuel casks in use in the United States are designed to be stored vertically. Most canister-based systems also are designed for vertical storage, but one over-pack

⁵ The term *bare fuel* refers to the entire fuel assembly, including the uranium pellets within the fuel rods.

system is designed as a horizontal concrete module (FIGURE 4.2).⁶ The principal characteristics of dry cask storage systems are summarized in TABLE 4.3, which is located at the end of this chapter.

Dry casks are designed to hold up to about 10 to 15 metric tons of spent fuel. This is equivalent to about 32 pressurized water nuclear reactor (PWR) spent-fuel assemblies or 68 boiling water nuclear reactor (BWR) spent-fuel assemblies. Although the dimensions vary among manufacturers, fuel types (i.e., BWR or PWR fuel) and amounts of fuel stored, the casks are typically about 19 feet (6 meters) in height, 8 feet (2.5 meters) in diameter, and weigh 100 tons or more when loaded.

The casks (for bare-fuel designs) or canisters (for canister-based designs) are placed directly into the spent fuel pool for loading. After they are loaded, the canisters or casks are drained, vacuum dried, and filled with an inert gas (typically helium). The loaded canisters or casks are then removed from the pool, their outer surfaces are decontaminated,⁷ and they are moved to the dry storage facility on the property of the reactor site. Loading of a single cask or canister can take up to one week. The vacuum drying process is the longest step in the loading process.

In the United States, dry casks are stored on open concrete pads within a protected area of the plant site.^{8,9} This protected area may be contiguous with the protected area of the plant itself or may be located some distance away in its own protected area (see FIGURE 2.1).

According to the information provided to the committee by cask vendors, nuclear power plant operators are currently purchasing mostly dual-purpose casks for spent fuel storage. The horizontal NUHOMS cask design is one of the most-ordered designs at present (TABLE 4.3). The vendors informed the committee that cost is the chief consideration of their customers when making purchasing decisions. Cost considerations are driving the cask industry away from all-metal cask designs and toward concrete designs for storage.

⁶ In addition, there is one modular concrete vault design in the United States: The Fort St. Vrain, Colorado, Independent Spent Fuel Storage Installation, which stores spent fuel from a high-temperature gas-cooled reactor. This reactor operated until 1989 and is now decommissioned. Because this is a one-of-a-kind facility, and the time available to the committee was short, it was not examined in this study.

⁷ Small amounts of radioactive contamination are present in the cooling water in the spent fuel pool. Some of this contamination is transferred to the cask surfaces when it is immersed in the pool for loading.

⁸ There may be exceptions in the future. Private Fuel Storage has requested a license from the Nuclear Regulatory Commission to construct a dry cask storage facility in Utah that will store fuel from multiple reactor sites. An underground dry cask storage facility has been proposed at the Humbolt Bay power plant in California to store old, low decay-heat fuel. The underground design is being proposed primarily because the site has very demanding seismic design requirements and is possible only because the fuel to be stored generates little heat.

⁹ In Germany, dry casks are stored in reinforced concrete buildings. These buildings were originally designed to provide additional radiation shielding (over what is provided by the cask itself) to reduce doses at plant site boundaries to background levels. Some of these buildings are sufficiently robust to provide protection against crashes of large aircraft. A subgroup of the committee visited spent fuel storage sites at Ahaus and Lingen during this study. See Appendix C for details.

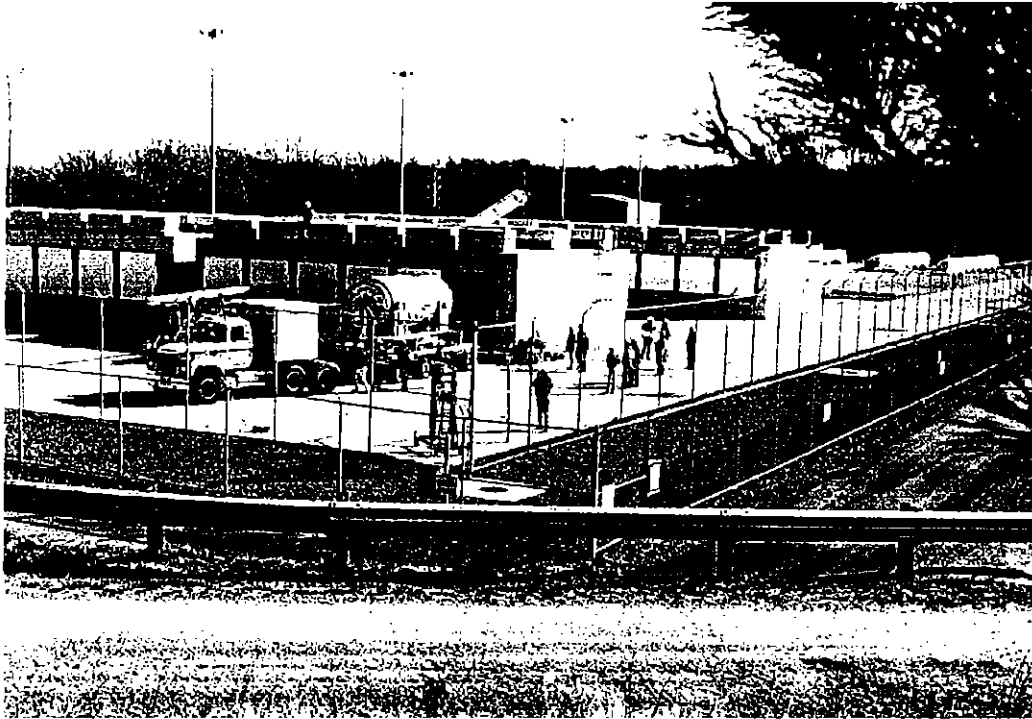


FIGURE 4.2 Photo showing a canister being loaded into a NUHOMS horizontal storage module. SOURCE: Nuclear Regulatory Commission.

4.2 EVALUATION OF POTENTIAL RISKS OF DRY CASK STORAGE

Dry casks were designed to ensure safe storage of spent fuel,¹⁰ not to resist terrorist attacks. The regulations for these storage systems, which are given in Title 10, Part 72 of the Code of Federal Regulations (i.e., 10 CFR 72), are designed to ensure adequate passive heat removal and radiation shielding during both normal operations, off-normal events, and accidents. The latter include, for example, accidental drops or tip-overs during routine cask movements. The robust construction of these casks provides some passive protection against external assaults, but the casks were not explicitly designed with this factor in mind.¹¹

The regulations in 10 CFR 72 require that dry cask storage facilities (formally referred to as Independent Spent Fuel Storage Installations, or ISFSIs) be located within a protected area of the plant site (see FIGURE 2.1). However, the protection requirements for these installations are lower than those for reactors and spent fuel pools. The guard force is required to carry side arms, and its main function is surveillance: To detect and assess threats and to summon reinforcements. If the ISFSI is within the protected area of the plant

¹⁰ Dual-purpose casks also were designed for safe transport under the requirements of Title 10, Part 71 of the Code of Federal Regulations. The committee did not examine transport of spent fuel in this study.

¹¹ A recent study by the German organization GRS (Gesellschaft für Anlagen- und Reaktorsicherheit, MBH) examined the vulnerability of the Castor-type casks to large-aircraft impacts.

it would come directly under the protection of plant's guard forces. The protected area is surrounded by vehicle barriers to protect against the detonation of a design-basis threat vehicle bomb.¹²

A terrorist attack that breached a dry cask could *potentially* result in the release of radioactive material from the spent fuel into the environment through one or both of the following two processes: (1) Mechanical dispersion of fuel particles or fragments; and (2) dispersion of radioactive aerosols (e.g., cesium-137). As described in Chapter 3, the latter process would have greater offsite radiological consequences. The committee evaluates the potential for both of these processes later in this chapter.

In the wake of the September 11, 2001 attacks, additional work has been or is being carried out by government and private entities to assess the security risks to dry casks from terrorist attacks. Sandia National Laboratories is currently analyzing the response of dry casks to a number of potential terrorist attack scenarios at the request of the Nuclear Regulatory Commission. The committee was briefed on these analyses at two of its meetings.

Sandia is analyzing the responses of three vertical cask designs and one horizontal design to a variety of terrorist attack scenarios (FIGURE 4.3). These designs are considered to be broadly representative of the dry casks currently licensed for storage in the United States by the Nuclear Regulatory Commission (see TABLE 4.1 at the end of this chapter). The committee received briefings on these studies by Nuclear Regulatory Commission and Sandia staff.

Several attack scenarios are being considered in the Sandia analyses. They include large aircraft impacts and assaults with various types and sizes of explosive charges and other energetic devices. Details on the large aircraft impact scenarios are provided in the classified report.

Most of this work is still in progress and has not yet resulted in reviewable documents. Consequently, the committee had to rely on discussions with the experts who are carrying out these studies and its own expert judgment in assessing the quality and completeness of this work.

4.2.1 Large Aircraft Impacts

Sandia analyzed the impact of an airliner traveling at high speed into the four cask designs shown in FIGURE 4.3. These analyses examined the consequences of impacts of the fuselage and the "hard" components of the aircraft (i.e., the engines and wheel struts) into individual casks and arrays of casks on a storage pad. The latter analysis examined the potential consequences of cask-to-cask interactions resulting from cask sliding or partial tip-over. The objectives of the analyses were first to determine whether the casks would fail (i.e., the containment would be breached) and, if so, to estimate the radioactive material releases and their health consequences.

¹² As noted in Chapter 2, the committee did not examine surveillance requirements or the placement or effectiveness of vehicle barriers and guard stations at commercial nuclear plants.

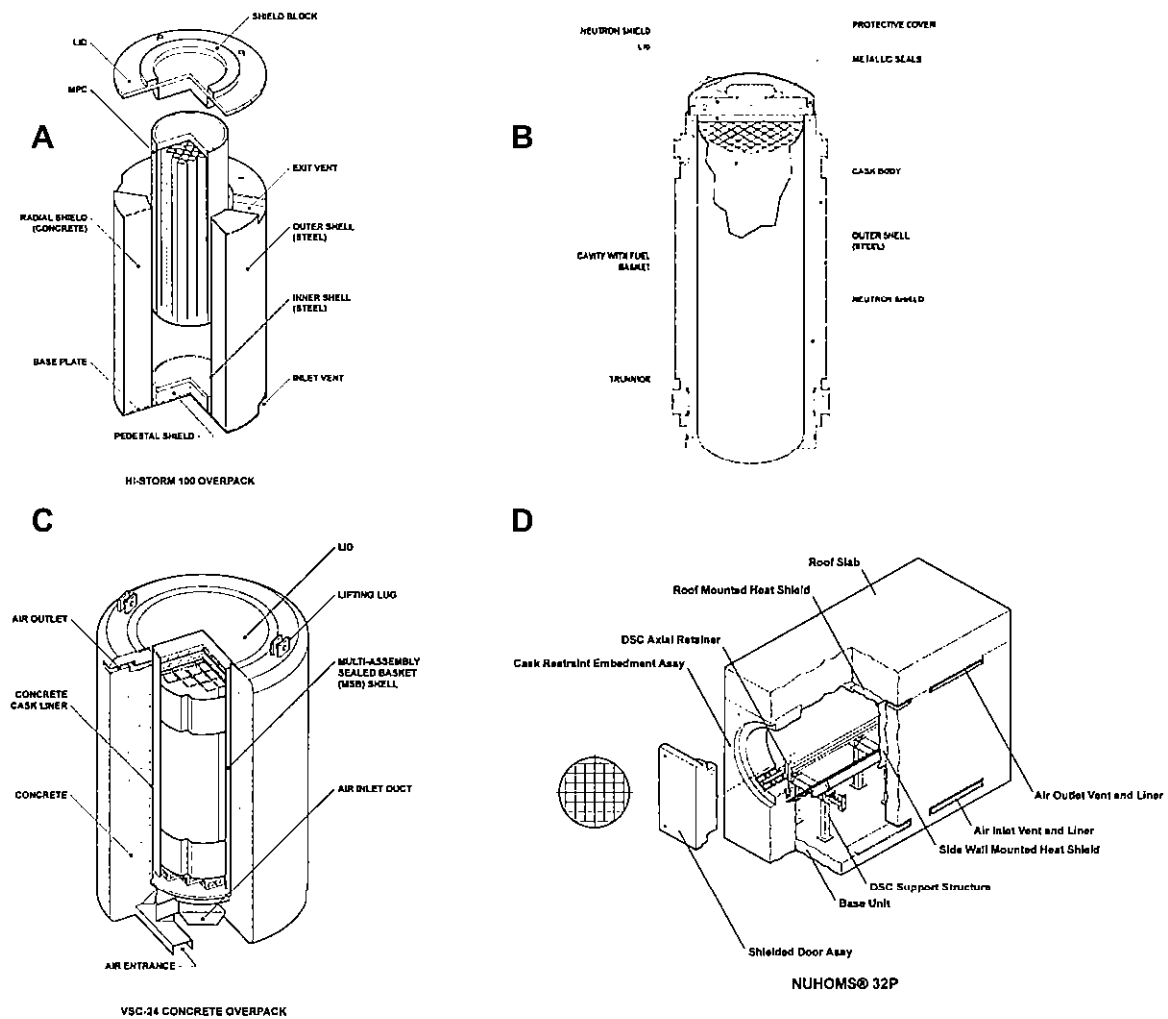


FIGURE 4.3 Four cask systems used in the Sandia analyses described in this chapter (A) HI-STORM-100. (B) TN-68. (C) VSC-24. (D) NUHOMS-32P. The casks shown in A, C, and D are canister-based casks; the cask shown in B is a bare-fuel cask. SOURCE: Nuclear Regulatory Commission.

The aircraft was modeled using Sandia-developed Eulerian CTH code (see footnote 15 in Chapter 3). The aircraft manufacturer (Boeing Corp.) was consulted to ensure that the aircraft model used in the analyses was accurate. The casks were modeled with standard finite element codes using the published characteristics of the casks. The casks were assumed to be filled with high-burnup, 10-year-old spent fuel. The fuel rods were assumed to fail (rupture) if the strains in the cladding exceeded one percent, which is a conservative assumption. Sandia evaluated the release of radioactive materials from the spent fuel pellets inside the fuel rods when such cladding failures occurred. Radiological consequences of such releases were calculated for “representative” (with respect to weather and population) site conditions for each cask based on the actual average conditions at the

site that currently stores the most spent fuel in that cask type.¹³ Site conditions differed for each cask.

The effects of jet fuel fires also were not considered in the analyses. Based on an analysis of actual aircraft accidents, Sandia determined that jet fuel would likely be dispersed over a large area in a low-angle impact. Consequently, the resulting petroleum fire would likely be of short duration (generally less than 15 minutes according to Sandia researchers). Long-duration fires that could damage the casks or even ignite the cladding of the spent fuel were not seen to be credible for the aircraft impact scenarios considered by Sandia.¹⁴

The results of these analyses, which are considered by the Nuclear Regulatory Commission to be classified or safeguards information, are detailed in the classified report. In general, the analyses show that some types of impacts will damage some types of casks. For some scenarios there could be substantial cask-to-cask interactions, including collisions and partial tip-overs.

Nevertheless, predicted releases of radioactive material from the casks, mainly noble gases, were relatively small for all of the scenarios considered by Sandia. The analyses show that the releases were governed by design-specific features of the casks. Sandia noted that the modeling of such releases is difficult and requires expert judgment for several elements of the calculation. Detailed calculations of the consequences were still in progress when the committee was briefed on these analyses.

4.2.2 Other Assaults

Analyses are also being carried out to understand the consequences of other types of assaults on the cask designs shown in Figure 4.3. These include assaults using explosives and certain types of high-energy devices. The analyses were still underway when the committee was briefed on these analyses, and the results were characterized by the Nuclear Regulatory Commission as preliminary. Details are provided in the classified report.

4.2.3 Discussion

As noted previously, the dry cask vulnerability analyses were still underway when the committee's classified study was completed. Based on the analyses it did receive, the committee judges that no cask provides complete protection against all types of terrorist attacks. The committee judges that releases of radioactive material from dry casks are low for the scenarios it examined with one possible exception as discussed in the classified report. It is not clear to the committee whether it is credible to assume that this "exceptional" scenario could actually be carried out.

¹³ As noted in Chapter 1, the committee did not concern itself with how radioactive materials would be transported through the environment once they were released from a dry cask. Rather, the committee confined its examination to whether and how much radioactive material might be released from a dry cask in the event of a terrorist attack.

¹⁴ The committee subgroup that visited Germany was briefed on a fire test on the Castor cask that involved a fully engulfing one-hour petroleum fire. The cask maintained its integrity during and after this test. See Appendix C. The results of this test do not necessarily translate to casks having other designs.

In the committee's opinion, there are several, relatively simple steps that could be taken to reduce the likelihood of releases of radioactive material from dry casks in the event of a terrorist attack:

- Additional surveillance could be added to dry cask storage facilities to detect and thwart ground attacks.¹⁵
- Certain types of cask systems could be protected against aircraft strikes by partial earthen berms. Such berms also would deflect the blasts from vehicle bombs.
- Visual barriers could be placed around storage pads to prevent targeting of individual casks by aircraft or standoff weapons.¹⁶ These would have to be designed so that they would not trap jet fuel in the event of an aircraft attack.
- The spacing of vertical casks on the storage pads can be changed, or spacers (shims) can be placed between the casks, to reduce the likelihood of cask-to-cask interactions in the event of an aircraft attack.
- Relatively minor changes in the design of newly manufactured casks could be made to improve their resistance to certain types of attack scenarios.

4.3 POTENTIAL ADVANTAGES OF DRY STORAGE OVER WET STORAGE

Based on the analyses presented in Chapter 3 and previously in this chapter, the committee judges that dry cask storage has several potential safety and security advantages over spent fuel pool storage. These differences can best be illustrated using scenarios for both storage systems based on the Sandia analyses reviewed by the committee. **The use of such scenarios should not be taken to imply that the committee believes that these scenarios are likely or even possible at all storage facilities. They are used only for illustrative purposes.**

The following statements can be made about the comparative advantages of dry-cask storage and spent fuel storage based on the Sandia analyses:

Less spent fuel is at risk in an accident or attack on a dry-storage cask than a spent fuel pool. An accident or attack on a dry cask storage facility would likely affect at most a few casks and put a few tens of metric tons of spent fuel at risk. An accident or attack on a spent fuel pool puts the entire inventory of the pool, potentially hundreds of metric tons of spent fuel, at risk.

The potential consequences of an accident or terrorist attack on a dry cask storage facility are lower than that for a spent fuel pool. There are several reasons for this difference:

- (1) There is less fuel in a dry cask than that in a spent fuel pool and therefore less radioactive material available for release.

¹⁵ As noted in Chapter 1, the committee did not examine surveillance activities at nuclear power plants and has no basis to judge whether current activities at dry cask storage facilities are adequate.

¹⁶ The ISFSI at the Palo Verde Nuclear Power Plant in Arizona, which was visited by a subgroup of committee members, incorporates a berm into its design to provide a visual barrier.

- (2) *Measured on a per fuel assembly basis*, the inventories of radionuclides available for release from a dry cask are lower than those from a spent fuel pool because dry casks store older, lower decay-heat fuel.
- (3) Radioactive material releases from a breach in a dry cask would occur through mechanical dispersion.¹⁷ Such releases would be relatively small. Certain types of attacks on spent fuel pools could result in a much larger dispersal of spent fuel fragments. Radioactive material releases from a spent fuel pool also could occur as the result of a zirconium cladding fire, which would produce radioactive aerosols. Such fires have the potential to release large quantities of radioactive material to the environment.

The recovery from an attack on a dry cask would be much easier than the recovery from an attack on a spent fuel pool. Breaches in dry casks could be temporarily plugged with radiation-absorbing materials until permanent fixes or replacements could be made. The most significant contamination would likely be largely confined to areas near the cask storage pad and could be detected and decontaminated. The costs of recovery could be high, however, especially if the cask could not be repaired or the spent fuel could not be removed with equipment available at the plant. A special facility might have to be constructed or brought onto the site to transfer the damaged spent fuel to other casks.

Breaches in spent fuel pools could be much harder to plug, especially if high radiation fields or the collapse of the overlying building prevented workers from reaching the pool. Complete cleanup from a zirconium cladding fire would be extraordinarily expensive, and even after cleanup was completed large areas downwind of the site might remain contaminated to levels that prevented reoccupation (see Chapter 3).

It is the potential for zirconium cladding fires in spent fuel pools that gives dry cask storage most of its comparative safety and security advantages. This comparative advantage can be reduced by lowering the potential for zirconium cladding fires in loss-of-pool-coolant events. As discussed in Chapter 3, the committee believes that there are at least two steps that can be implemented immediately to lower the potential for such fires.

4.4 FINDINGS AND RECOMMENDATIONS

With respect to the committee's task to examine potential safety and security advantages of dry cask storage using various single-, dual-, or multi-purpose cask designs, the committee offers the following findings and recommendations:

FINDING 4A: Although there are differences in the robustness of different dry cask designs (e.g., bare-fuel versus canister-based), the differences are not large when measured by the absolute magnitudes of radionuclide releases in the event of a breach.

All storage cask designs are vulnerable to some types of terrorist attacks for which

¹⁷ Since the committee's classified report was published, the committee received an additional briefing from the Nuclear Regulatory Commission which suggests that a radioactive aerosol could be released in one type of terrorist attack. However, the scenario in question does not appear to the committee to be credible.

radionuclide releases would be possible. The vulnerabilities are related to the specific design features of the casks, but the committee judges that the quantity of radioactive material releases predicted from such attacks is still relatively small.

FINDING 4B: Additional steps can be taken to make dry casks less vulnerable to potential terrorist attacks.

Although the vulnerabilities of current cask designs are already small, additional, relatively simple steps can be taken to reduce them. Such steps are listed in Section 4.2.3.

RECOMMENDATION: The Nuclear Regulatory Commission should consider using the results of the vulnerability analyses for possible upgrades of requirements in 10 CFR 72 for dry casks, specifically to improve their resistance to terrorist attacks.

The committee was told by Nuclear Regulatory Commission staff that such a step is already under consideration. Based on the material presented to the committee, there appear to be minor changes that can be made by plant operators and cask vendors to increase the resistance of existing and new casks to terrorist attacks (see Section 4.2.3).

With respect to the committee's task to examine the safety and security advantages of dry cask storage versus wet pool storage at reactor sites, the committee offers the following findings and recommendations:

FINDING 4C: Dry cask storage does not eliminate the need for pool storage at operating commercial reactors.

Newly discharged fuel from the reactor must be stored in the pool for cooling, as discussed in detail in Chapter 3. Under current U.S. practices, dry cask storage can only be used to store fuel that has been out of the reactor long enough (generally greater than 5 years under current practices) to be air cooled. The fuel in dry cask storage poses less of a risk in the event of a terrorist attack than newly discharged fuel in pools because there is substantially reduced probability for initiating a cladding fire.

FINDING 4D: Dry cask storage for older, cooler spent fuel has two inherent advantages over pool storage: (1) It is a passive system that relies on natural air circulation for cooling; and (2) it divides the inventory of that spent fuel among a large number of discrete, robust containers. These factors make it more difficult to attack a large amount of spent fuel at one time and also reduce the consequences of such attacks.

Each storage cask holds no more than about 10 to 15 metric tons of spent fuel, compared to the several hundred metric tons of spent fuel that is commonly stored in reactor pools. The robust construction of these casks prevents large-scale releases of radionuclides in all of the attack scenarios examined by the committee. Some of the attacks could breach the casks, but many of these breaches would be small and could probably be more easily plugged than a perforated spent fuel pool wall because radiation fields would be lower and there would be no escaping water to contend with. Even large breaches of the cask would

result only in the mechanical dispersal of some of its radionuclide inventory in the immediate vicinity of the cask.

FINDING 4E: Depending on the outcome of plant-specific vulnerability analyses described in the committee's classified report, the Nuclear Regulatory Commission might determine that earlier movements of spent fuel from pools into dry cask storage would be prudent to reduce the potential consequences of terrorist attacks on pools at some commercial nuclear plants.

The statement of task directs the committee to examine the risks of spent fuel storage options and alternatives for decision makers; not to recommend whether any spent fuel should be transferred from pool storage to cask storage. In fact, there may be some commercial plants that, because of pool designs or fuel loadings, may require some removal of spent fuel from their pools. If there is a need to remove spent fuel it should become clearer once the vulnerability and consequence analyses described in Chapter 3 are completed. The committee expects that cost-benefit considerations would be a part of these analyses.

TABLE 4.1 Dry Casks Used for Spent Fuel Storage in the United States

Cask design used for storage	License holder	Type	Fuel type	Construction	Closure system	Number of casks used to date; sites; and number of casks on order ¹
CASTOR V/21	GNSI (General Nuclear Systems, Inc.)	Bare fuel, storage-only	BWR	Ductile cast iron	Primary lid (44 bolts), secondary lid (48 bolts)	25 loaded (Surry); 0 purchased
CASTOR X/33	GNS (Gesellschaft für Nuklear-Service mbH)	Bare fuel, storage-only	PWR	Ductile cast iron	Primary lid (44 bolts), secondary lid (70 cup screws)	1 loaded (Surry); 0 purchased
NAC S/T	NAC International	Bare fuel, storage-only	PWR	Inner and outer stainless steel shells	Closure lid (24 bolts)	2 loaded (Surry); 0 purchased
MC-10	Westinghouse	Bare fuel, storage-only	PWR	Stainless and carbon steel	One shield lid and two sealing lids, all bolted (number of bolts not available)	1 loaded (Surry); 0 purchased
TN-32, TN-40	Transnuclear Inc.	Bare fuel, storage-only	PWR	Carbon steel	One lid (48 bolts)	61 loaded (4 sites); 22 purchased
TN-68	Transnuclear Inc.	Bare fuel, dual-purpose	BWR	Carbon steel	One lid (48 bolts)	24 loaded (Peach Bottom); 20 purchased
Fuel Solution W-150 Storage Cask	BNFL Fuel Solutions	Canister-based, dual-purpose	PWR, BWR	Reinforced concrete with inner steel shell	Canister lid, welded cask lid (12 bolts)	7 loaded (Big Rock Point); 0 purchased
HI-STORM 100	Holtec International	Canister-based, storage-only module	PWR, BWR	Stainless steel shells with un-reinforced concrete filler	Canister lid, welded cask lid (4 bolts)	58 loaded (7 sites); 177 on order
HI-STAR 100	Holtec International	Canister-based, dual-purpose	PWR, BWR	Carbon steel shells with neutron absorber polymer	Canister lid, welded cask lid (54 bolts)	7 loaded (2 sites ¹); 5 on order

VSC-24 Ventilated Concrete Cask	BNFL Fuel Solutions	Canister- based, storage-only	PWR	Reinforced concrete with inner steel shell	Canister lid, welded Cask lid (6 bolts)	58 loaded (3 sites); 4 ² purchased
NAC-MPC	NAC International	Canister- based, dual- purpose	PWR	Metal canister surrounded by storage overpack. Storage overpack consists of an inner steel liner 3.5 in. thick, two rebar cages, and concrete	Canister lid, welded. Cask lid over a shield plug (6 high-strength bolts)	21 loaded (Yankee Rowe and CT Yankee); 59 purchased
NAC-UMS	NAC International	Canister- based, dual- purpose	PWR, BWR	Metal canister surrounded by storage overpack. Storage overpack consists of inner steel liner 2.5 in. thick, two rebar cages, and concrete	Canister lid, welded Cask lid over a shield plug (6 high-strength bolts)	80 loaded (2 sites); 165 purchased
Holtec MPC 24E/EF	Holtec International	Canister based, dual- purpose	PWR, BWR	Metal canister surrounded by storage overpack. Storage overpack consists of inner and outer steel liners, a double- rebar cage, and concrete	Canister lid, welded Cask lid, shield plug plus 48 bolts	34 loaded (Trojan); 0 purchased
NUHOMS 24P, 52B, 61BT, 24PT1, 24PT2, 32PT	Transnuclear Inc.	Canister- based, dual- purpose	PWR, BWR	Horizontal reinforced concrete storage module with shielded canister	Canister lid, welded Storage module lid, reinforced concrete	239 loaded (10 sites); >150 purchased

NOTES:

¹The Humboldt Bay Power Plant is licensing a site-specific variation of the HI-STAR System called HI-STAR HB.

² Some licensees have purchased additional casks that have not yet been loaded, nor are they planned for loading.

SOURCES: Cask license holders.