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FFTF DISPOSABLE SOLID WASTE CASK

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JD Thomson (WHC)
SD Goetsch (Nuclear Pkg., Inc.)

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FFTF DISPOSABLE SOLID WASTE CASK: A STUDY IN THE EFFECTIVENESS OF CONCRETE AS A PACKAGING MATERIAL

Stephen D. Goetsch, Nuclear Packaging, Inc.
James D. Thomson, Westinghouse Hanford Co.

ABSTRACT

Disposal of radioactive waste from the Fast Flux Test Facility (FFTF) will utilize a Disposable Solid Waste Cask (DSWC) for the transport and burial of irradiated stainless steel and inconel materials. Retrievability coupled with the desire for minimal facilities and labor costs at the disposal site identified the need for the DSWC. Design requirements for this system were patterned after Type B packages as outlined in 10 CFR 71 with a few exceptions based on site and payload requirements. A summary of the design basis, supporting analytical methods and fabrication practices developed to deploy the DSWC is provided in this paper.

INTRODUCTION

The plan for the disposal of radioactive solid waste from the Fast Flux Test Facility (FFTF) utilizes a special waste handling cask. This concrete and steel Disposable Solid Waste Cask (DSWC) will be loaded at a transloading facility at FFTF and then transported to a burial site on the Hanford Reservation near Richland, Washington.

Radioactive solid waste generated during the operation of the FFTF consists of activated test assembly hardware, reflectors, in-core shim assemblies and control rods. This radioactive waste will be cleaned (sodium removed) prior to disposal. Retrievability coupled with the desire for minimal facilities and labor costs at the disposal site identified the need for the DSWC. A summary of the design basis, supporting analytical methods and fabrication practices developed to deploy the DSWC is provided in this paper.

The DSWC shown in Figure 1 is a reinforced concrete cask fabricated with a carbon steel liner, which serves as a pressure boundary. Shielding is provided by the reinforced concrete sidewalls, steel end plugs, the steel liner, and auxiliary shielding around the center portion of the liner. By adjusting the thickness of this auxiliary shielding, as well as the density of the concrete, the DSWC can be configured to accommodate various payload source terms.

FFTF DISPOSABLE SOLID WASTE CASK

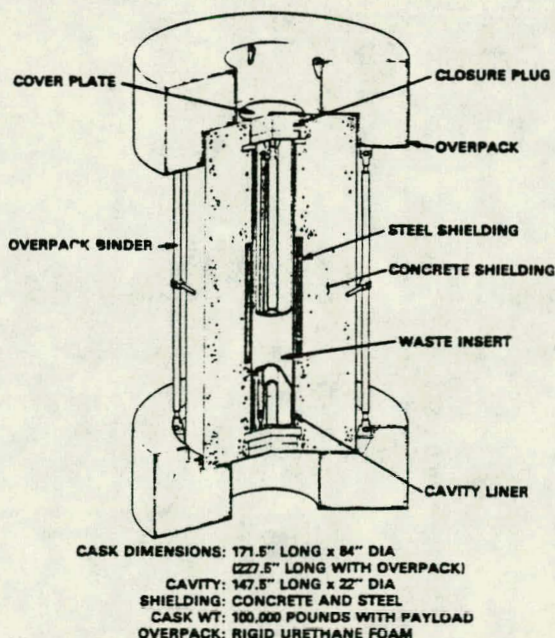


FIGURE 1

Prior to starting the design activity for this cask, a parametric study was conducted to select the most cost effective configuration for the disposable cask. Efforts were made to reduce the unit cost of the DSWC by reusing as much equipment and components for the lifting and handling equipment as possible. For the purpose of this study, two design basis payloads were considered. The first, the Reference payload, was identified to represent the 1512-watt heat load and irradiation source equivalent to six FFIF Reflector Assemblies. The second was identified as the Nominal payload and was to represent an 800-watt decay heat level equivalent to six driver assemblies without fuel pins. Most of the casks to be procured to support FFIF solid waste handling and related activities will be of the nominal type.

Key design parameters for the casks were:

Loaded Weight:	100,000 pounds
Closure Plug Weight:	1,900 pounds
Outer diameter	84 inches
Cavity Dimensions:	
Diameter	22 inches
Length	147.9 inches

Vertical transport and handling of the DSWC was selected to reduce support equipment costs and the additional handling time. The additional resources necessary to rotate the cask to the horizontal position prior to transport and then up-end it in the field were, therefore, not required.

The DSWC is a top-loading cask and is fitted with a carbon steel closure plug. The plug is designed to be handled remotely using a special plug handling fixture. After the waste insert is placed in the DSWC, the closure plug is installed. The reusable plug handling grappling ring is then removed from the top surface of the cask closure plug. The weight of the plug is sufficient to compress an elastomer gasket beneath the plug. This serves as a temporary seal until a steel retaining cover plate can be welded to the top surface of the plug housing. After a check of the closure seal weld, the DSWC is ready to be transported to the disposal site. Three lift points are provided at the top surface of the cask. Three reusable lifting lugs are bolted to threaded coil loop inserts provided in the top surface of the cask. These inserts are cast in place during fabrication of the concrete cask assembly. The reusable lifting lugs are removed after transport of the cask to the disposal site and returned to storage to be used with the next DSWC.

The DSWC is transported on a specially-designed low-boy truck transporter in a vertical attitude with upper and lower polyurethane overpack end-cap units installed. One set of ratchet binders is used to secure the overpack units around the cask. A second set of binders ties the overpack-cask assembly to the transporter when loaded. The nominal and reference DSWC configurations are designed with concrete densities of 145 and 157 pounds per cubic foot, respectively. The auxiliary steel shielding is required only over the center 48 inches of the liner where the high energy photon source is most intense. Above and below this zone, steel studs are attached to the outside of the steel liner to anchor the steel subassembly to the reinforced concrete structure. After fabrication of the cask, the exterior surface of the cask was to be coated with epoxy for moisture protection.

DESIGN REQUIREMENTS

The design requirements for the DSWC were patterned after 10 CFR 71 Type B packages and modified to accommodate on-site handling and payload requirements. The solid waste material to be loaded into this cask will be predominantly stainless steel hardware with some additional inconel parts.

The primary radioactinants comprising this solid waste are:

- 312.5-day half-life isotope Mn-54 which results from a (n,p) reaction in iron;
- 71.3-day half-life isotope Co-58, which results from a (n,p) reaction in nickel;
- 115-day half-life isotope Ta-182, which results from a (n,γ) reaction in the tantalum impurity in steel; and
- 5.27 year half-life isotope Co-60, which results from both a (n,γ) reaction with the cobalt impurity in steel, and a (n,p) reaction with nickel in both steel and inconel.

Each of these radioisotopes emit relatively high energy photons which require significant amounts of shielding.

The cask was to be passively cooled with an internal nitrogen, argon or air gas environment. The design basis decay heat level was set at 1512 watts. The maximum allowable dose on the external surface of the cask was set at 200 mrem per hour.

The DSWC was to be designed to provide the capability for waste retrievability after 20 years of storage above or below ground. Structural integrity was required for the 20-year design life of the cask. Design of the primary containment was to be in accordance with

Section VIII, Division I of the ASME Code and structural design in accordance with the USC Manual of Steel Construction.

Under normal transport conditions, the allowable stresses in the DSWC were not to exceed $\frac{1}{3}$ of yield or $\frac{1}{5}$ of ultimate, whichever was less. Transport hypothetical accident conditions consisted of an eight-foot drop onto a flat horizontal surface and a 40 inch drop onto a mild steel bar six inches in diameter. Under these conditions the maximum allowable external dose was not to exceed 1000 mrem/hour at three feet. No hypothetical event was to result in ejection of the contents of the cask. Hypothetical handling accident conditions consisted of a four-foot drop onto a flat surface, a 20-foot drop into the cask loading station at FFTF, and an unrestrained rotational fall from a vertical to a horizontal attitude.

DSWC DESIGN EFFECTIVENESS

The selection of concrete as the major shield material is the most unique feature of the Disposable Solid Waste Cask. The structural and shielding properties of concrete are highly adaptable depending on the specific requirements of a design. Using special aggregates, the shielding properties of concrete were varied by controlling the density to suit the two DSWC payloads. A common cask size and shape could then be used for both payloads while remaining within the operational limits imposed on the project.

The nominal payload, described above, has a source term lower than the reference payload. Also, by designing a wrapped steel auxiliary shield (Figures 1 and 2) around the most highly activated part of the payload, the use of normal weight concrete was made feasible for the nominal payload design. Because the majority of projected waste was to be the nominal type, this had a significant effect on the final cask cost.

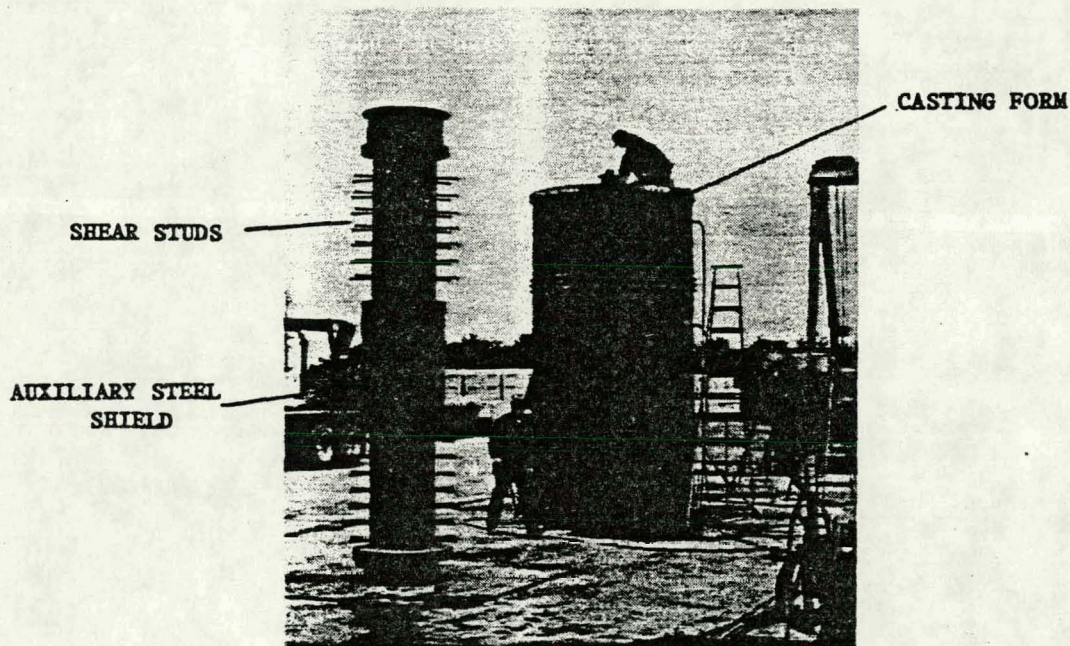


FIGURE 2 DSWC AUXILIARY SHIELD

Shielding calculations determined that the reference payload would require a more effective concrete shield design as well as a thicker auxiliary shield to attenuate the higher photon flux. By replacing some of the local gravel aggregates with some iron-rich aggregates normally used for decorative purposes, the density was increased approximately 15% over normal weight concrete. The resulting surface dose rate profile of the reference design was very similar to the nominal design, and both designs approach the design maximum allowable surface dose rate limit of 200 mrem only in three areas: around the central area corresponding to the area of peak radioactivity and at both ends, and near the central steel core.

Because the shield design of the nominal and reference payload casks differ only in ways that do not affect the size and shape of the casks, common operational procedures and support equipment can be used on both designs. The casks are handled by means of a three point lifting fixture (Figure 3) which also could be used to lift the bottom overpack simultaneously if the cask is to be lifted more than four feet from the ground. The structural interface between the lifting fixture and the concrete cask surface is effected by 12 imbedded lifting inserts, of the type commonly used in the concrete pre-fab industry. These inserts (shown in their placement jig in Figure 4) attach to the lifting fixture through special coil bolts.

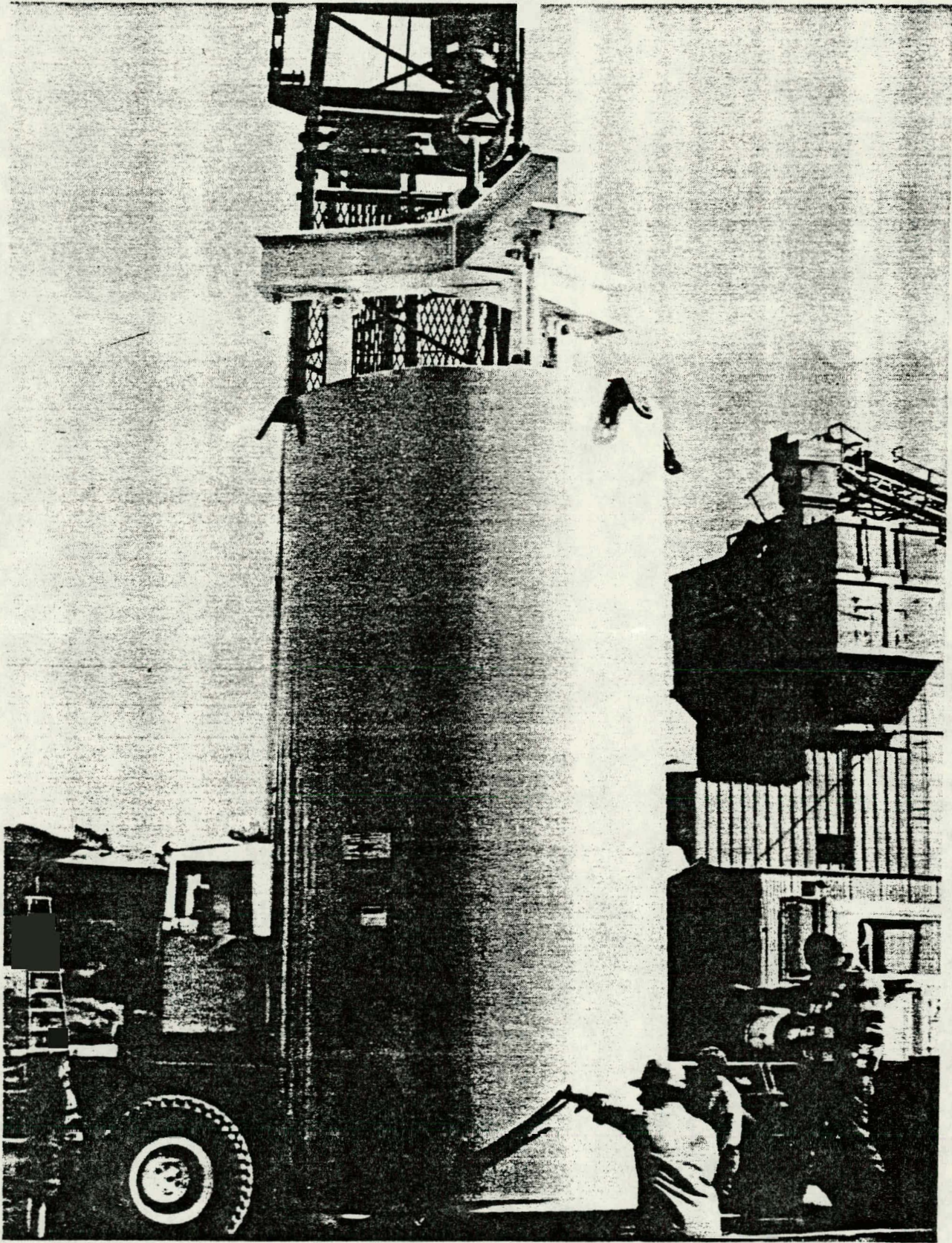


FIGURE 3 THREE-POINT LIFT FIXTURE

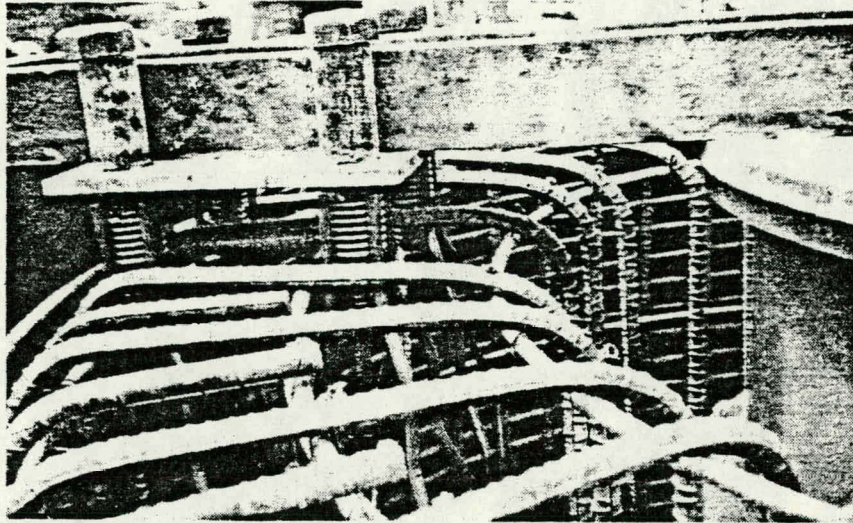


FIGURE 4 LIFTING INSERTS AND PLACEMENT FIXTURE

Analysis of the postulated accident conditions represented the major engineering effort in the design of the DSWC. Of the five separate hypothetical accident conditions imposed on the design, only the eight foot drop, a transport accident condition mitigated by the effects of the overpack, was analyzed by conventional methods. Concrete, being a brittle material, has significantly different dynamic characteristics than steel or lead. Even very high quality concretes will not develop shear strengths greater than 5% of their compressive strength. Common industry practice is to assume concrete has no tensile strength whatsoever. Concrete will shatter or pulverize under high impact loads, rather than squash, as ductile steel will. The design of the reinforcing steel in the concrete had to be capable of retaining and confining the concrete mass so that some shielding capability remains. (See Figure 4.)

Because very little research has been done on the behavior of concrete under impact loads, a new analysis approach was developed. This approach involved determining the mass of pulverized concrete from its compressive strength and the amount of compressive area required to develop that strength. Sufficient steel reinforcing was provided to prevent large cracks from opening in the remaining concrete mass. These methods have subsequently been tested to verify their reliability, as shown in Figure 5.

Analysis indicated that a fairly heavy, closely spaced, 1/2 inch reinforcing steel spiral and long, 3/4 inch shear studs welded to the steel inner liner would be required to resist the effects of a four foot bare cask drop (Figure 2 and 3). This much reinforcing reduced the predicted cracking due to thermal load effects imposed on the cask. It also created a steel net through which the six-inch diameter mild steel post from the design requirements could not easily penetrate.

The twenty-foot drop onto the CLS elevator scenario required the use of an impact limiter to be placed in the waste handling facility elevator. This was problematic, operationally, since tolerances for fit-up of the pad with the cask and the elevator had to be loose enough to allow reasonably easy installation, yet tight enough to permit the cask to interface with loading equipment in the CLS. This was solved by imposing fairly tight tolerances on the construction of the cask (diameter to within 1/8 inch and concentricity to within 1/4 inch, 14 feet from the datum) as well as by providing some adjustability in the pad itself.

Concrete, a very durable material, will remain functional for the design life of 20 years. A flexible epoxy coating was applied to the exterior surface to minimize weathering and freeze-thaw effects. The finished cask is shown in Figure 6. With minimum capital investment, a precast concrete contractor could cast two DSWC's a week. Because most containers could be made from normal weight concretes, no special handling or aggregates would be necessary. In large production runs, the cask could be produced economically (less than 20,000 USD).

LESSONS LEARNED IN FABRICATION

As stated above, precast concrete contractors, especially those specializing in concrete pipe, are ideally suited for placing the concrete shield in the DSWC. The concrete pipe industry is accustomed to tight dimensional requirements. Accelerated curing facilities are commonly available and the required quality control procedures are often already being implemented in some fashion.

Originally, it was thought that both the nominal and reference designs could have utilized from normally available aggregates by carefully controlling the mix design. Several attempts were made to do this, but these efforts proved unfeasible. Special aggregates were found, however, to increase the density to the required level. These aggregates, high in iron content, were found to be very reasonably priced compared to conventional heavy-weight aggregates.

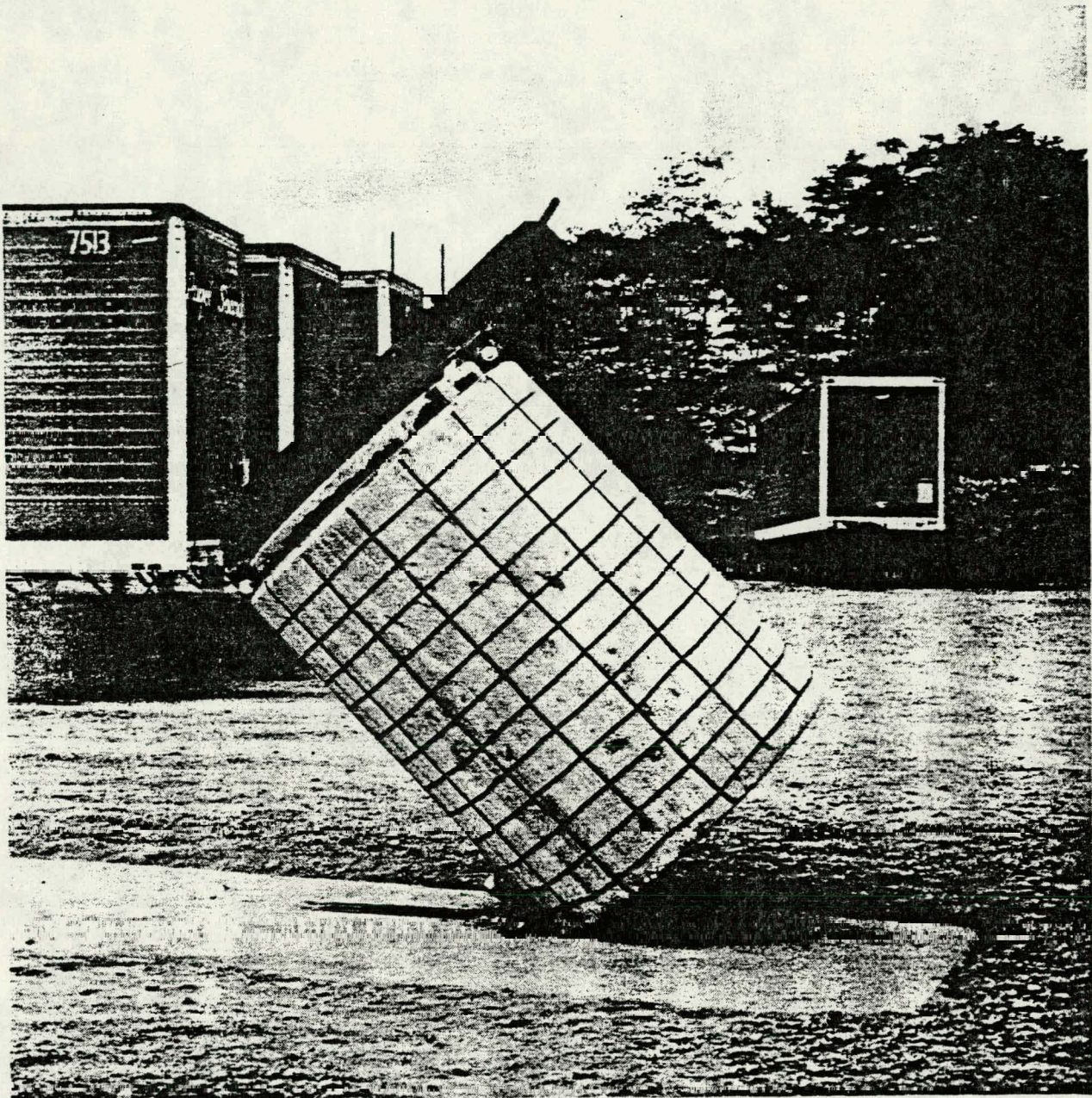


FIGURE 5 DROP TEST

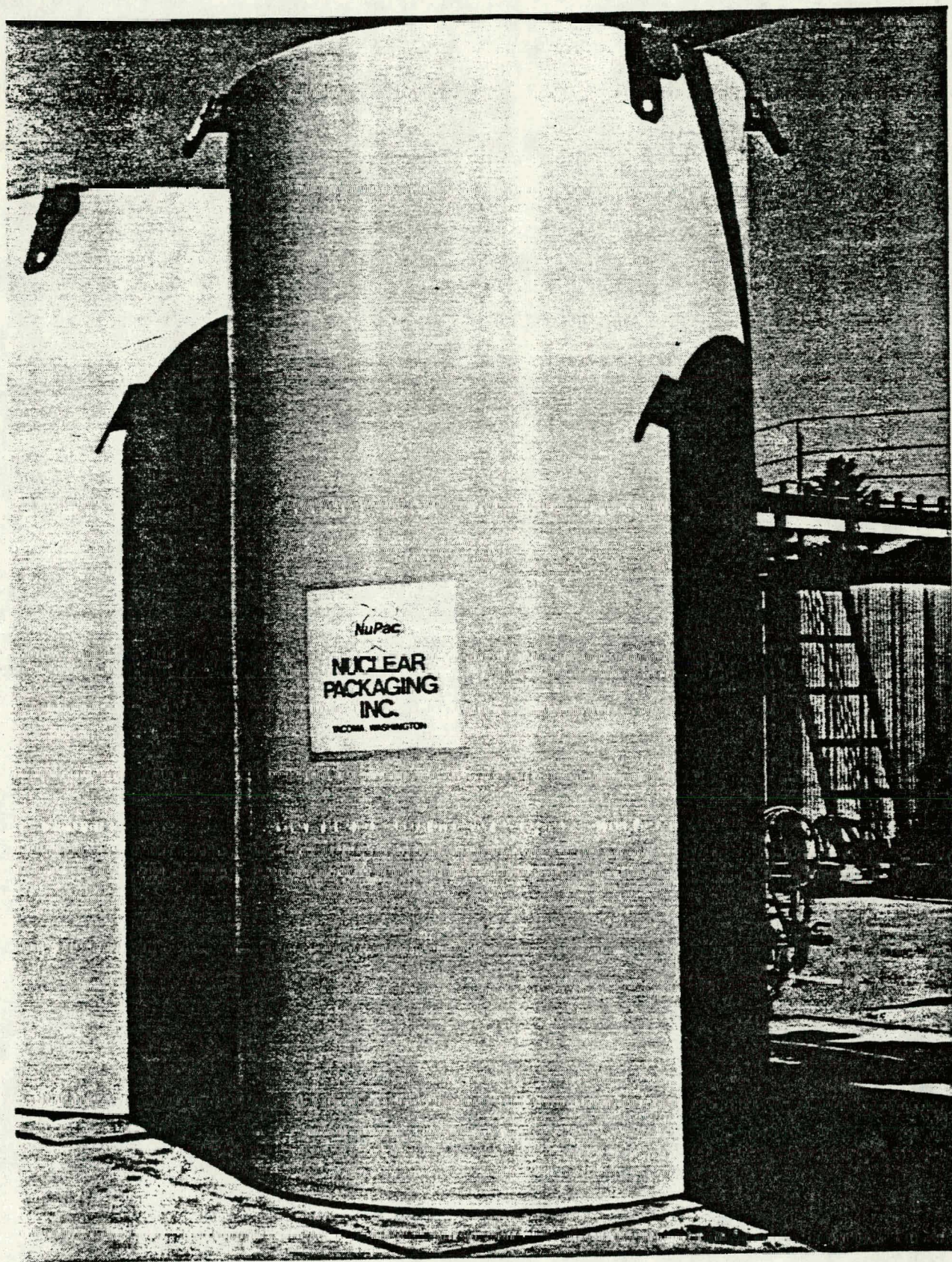


FIGURE 6 COMPLETED CASK

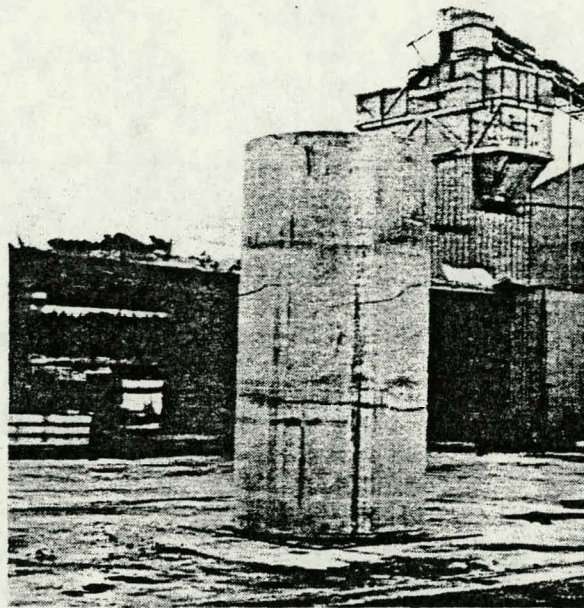


FIGURE 7 THERMAL-STRESS-INDUCED CRACKS -

During the initial cure of the casks, cracks were detected at approximately the one-third points on the sides of the casks (see Figure 7). These cracks would result from thermal stresses induced in the still very weak concrete during the first 48 hours of cure, and originate from the exothermic hydration process in the massive concrete shield. While characteristics of the solid payload as well as the design of the inner steel shell permitted minor cracking on the DSWC, efforts to minimize these cracks were initiated for informational purposes.

Since the cracks resulted from thermal gradient-induced loads, the cask cavities were filled with water and the water was allowed to trickle out over the outside of the casks. The heat of hydration in the center of the casks could then be transferred to the water, and carried out of the system. Also, for a period of approximately one week after the concrete was poured, the exterior of the casks were kept wet. The process would cause the still highly reactive cement inside the cracks to knit together, or heal, thus sealing the cracks. This process is used extensively to repair gas leaks from cracks in concrete pipes. After healing, the crack is nearly as strong in tension as the uncracked regions, and is essentially leakproof.

CONCLUSIONS

The DSWC program proved concrete to be a viable packaging material for both transport and disposal containers. It is economical, durable, and adaptable to many applications. Concrete is also the major component of a High Integrity Container built to handle the special needs of certain wastes coming out of the Three Mile Island (TMI) cleanup activities and has been proposed as a major component of on-site spent fuel and low-level waste containers. On this basis, concrete has proven to be a viable alternative for packaging of radioactive materials.

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