# The NLI-1/2 Tipover Accident

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## Introduction

On March 11, 1988, an empty NLI-1/2 truck cask tipped over while negotiating a right-hand turn on the Rockwell International Corporation (Rocketdyne) site in Canoga Park, California. The cask had been used to transport fuel to Idaho for the USDOE and was returning for another cask load, so the cask was empty at the time of the accident. The truck tractor remained upright, but the trailer turned over on its side, warping the trailer frame. The tractor/trailer rig was not speeding, and fortunately the driver was not injured in the accident. The cask was undamaged as the wooden impact limiters crushed sacrificially to protect the cask, and no radioactive material was released. Post-accident analysis determined that the cask center-of-gravity (CG) was high and the trailer frame was not stiff enough to resist the overturning forces of a reasonably sharp turn. Corrective action included changing the trailer to a stiffer frame with a drop-frame design to lower the cask center-of-gravity. The cask was returned to service after hydrostatic pressure tests and inspections showed that the cask was undamaged.

## ISO Container

The cask which tipped over was enclosed in an International Shipping Organization (ISO) shipping container of the type used for steamship cargos. This container is used for various types of heavy weight and hazardous cargos and is the preferred method of shipment on ships. Such

containers are designed to be handled by seaport cranes and restrained within the hold of a ship, and are designed in accordance with the International Shipping Organization and American Bureau of Shipping (ABS) standards. These standards require a load test with a safety factor of two on the rated capacity of the container before certification. The containers were designed with the concentrated loads of the spent fuel casks in mind, and have been analyzed to show at least a safety factor of two in the container floor beams.

The ISO container involved in the tipover incident suffered only minor damage to the side panels, and was refurbished. When repairs were complete, the container was load tested as a necessary step to allow recertification to the ISO and ABS standards. NAC believes that the conservative design and load testing required of ISO containers and their attachments to trailers makes these containers a viable means of transport of the casks.

**Trailers**

The NLI-1/2 cask is designed to carry one PWR or two BWR assemblies on a flatbed trailer design manufactured by TSI. This trailer is dedicated to NLI-1/2 cask shipments and the cask support structure is permanently welded to the trailer. Overseas shipment of the cask in an ISO container requires movement of the cask to and from a seaport on a trailer designed to employ the ISO container attachment twistlocks. A standard, light-weight, ISO container trailer was obtained from the trailer manufacturer so that the cask in the ISO container would still achieve the legal weight limit. If a shipment exceeds the legal weight limit for road transport, overweight permits and travel restrictions are required, which markedly complicate movement of fuel.

Figure 1 shows that the cask in the ISO container on the light-weight trailer had too high a center-of-gravity (CG), and this caused a relatively high probability of tipover in any abnormal conditions. NAC decided to change to a drop-frame trailer manufactured by the Fontaine company, and the light-weight trailers were withdrawn from service. The Fontaine drop-frame trailer configuration lowers the CG below the original TSI trailer CG, and Figure 1 shows that this improves the

rollover probability by a factor of 2.1 compared to the light-weight trailer that actually tipped over. The torsional stiffness of the trailers was also calculated, as listed in Table 1, and indicates that the Fontaine trailer is as rigid as the TSI trailers and will not twist as easily as the light-weight trailer so that the chances of tipping are further reduced.

**Vehicle Turn Velocity**

A simplified analysis indicated that the tipped ISO configuration could maneuver in a 25-foot radius (the approximate radius of the right-hand turn at the accident site) at 13.5 mph without overturning, if the stiffness of the trailer is not considered. The original TSI trailers for the NLI cask could permit about a 1-mph faster turn, and the Fontaine dropframe configuration allows a tenth mph faster turn than the TSI, as shown in Table 1. The closeness of the allowable speeds is misleading since trailer frame resistance to tipover is not considered, and the tipover speed is proportional to the square root of the velocity. A more appropriate expression of trailer stability is shown in Figure 1 as the probability of tipover in a single vehicle accident. The tipover probability for standard eight-foot width trailers increases rapidly when the center-of-gravity is raised beyond 80 inches. Lowering the CG below this height reduces the tipover probability but further reductions lose effectiveness because other accident mechanisms begin to dominate.

**Impact Analysis**

The cask impact limiters were analyzed using the deflection measured after the accident, resulting in the conclusion that the cask experienced a 16-g load, equivalent to a 10-inch drop. The magnitude of the impact was mitigated by the twisting of the trailer frame as the trailer tipped over. The ISO twistlocks of the trailer remained engaged with the container so that the container remained mated to the trailer throughout the accident. Since this impact was less than the one-foot Normal Operation drop analyzed in the cask Safety Analysis Report, the cask was not overstressed.

The impact limiters at the cask upper and lower ends were crushed on one side by the impact, which occurred in a side drop orientation. The impact limiters were disassembled by removing the outer aluminum skins and removing the crushed balsa wood. New wood with the same density and grain as the original material was installed with glue of the same type used in the original manufacture. New aluminum skins were fabricated and the impact limiters were reassembled.

**Weld Requirements**

The bolted attachment of the cask support rail to the ISO container was not strong enough to resist the lateral loads involved in the tipover, and the cask support structure did not break at the preplanned breakaway welds, which are included in the structure. The cask support structure was bolted to the ISO container because the floor of most ISO containers is aluminum, used to save shipping weight. The mounting of the cask supports to the ISO container with bolts was designed to handle normal shipping loads with a safety factor of two, but was not capable of withstanding the side loads encountered in the tipover. The cask supports were welded to a steel rail to provide clearance for the impact limiters above the container floor, and the rail was bolted to the steel ISO container floor beams through the aluminum floor decking.

A modification was made to replace the aluminum floor plates with steel plates welded to the crossbeams of the ISO container, allowing the cask support structure to be welded to the steel plates. This modification also strengthened the floor of the ISO container.

**Corrective Actions**

The principal corrective actions intended to prevent recurrence of this accident were to replace the light-weight trailers with new drop frame trailers, which lowered the cask center-of-gravity considerably. The replacement trailers have a much stiffer frame, which resists the twisting loads caused by turns or jolting of the trailer by obstructions in the roadbed. The ISO container configuration may only be used when shipping fuel outside the continental United States, and the original

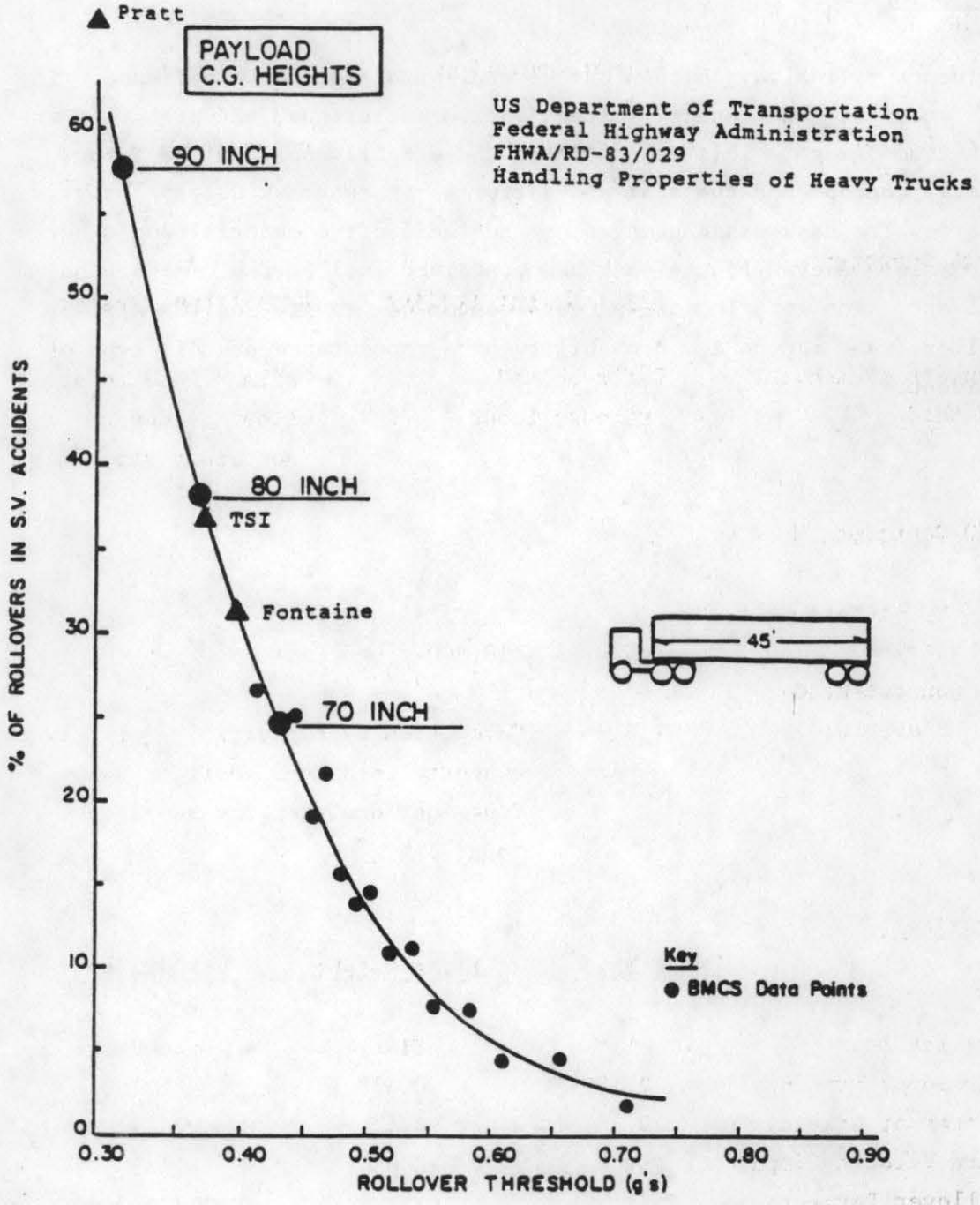
flatbed configuration is used for shipments which originate and terminate within the continental United States.

## Conclusion

Accidents will always happen but we can learn from the experience. In this accident, the impact limiters worked as intended and protected the cask from damage. This demonstrated the effectiveness of the impact limiter concept and the analyses performed in the cask Safety Analysis Report. The cask was undamaged, so no radioactive material would have been released even if the cask had contained fuel at the time of the accident. The lowering of the cask center-of-gravity and the stiffer trailer frame reduce the probability of a reoccurence of this type of accident.

FIGURE 1

TIPOVER PROBABILITY




Overlay of Rollover Thresholds Representing Payload C.G. Height Variations onto Accident Data Curve

**TABLE 1**

**DATA SUMMARY**

**Cask**

| | Normal Operation | Tipover Incident |
|---|---|---|
| Drop Height | 12 inches | 10 inches (equivalent) |
| G-Load | 16.3 g | 16 g |

**Cask Supports**

| | Light-Weight Trailer | Drop-Frame Trailer |
|---|---|---|
| Support Attachment Method | Rails bolted through floor | Rails welded to steel floor welded to container structure |

**ISO Container**

| | | |
|---|---|---|
| Safety Factors: | | |
| Lifting | 2.0 | (118,800-pound test load) |
| Concentrated Floor Load | 2.81 | (Calculated by applying 1/4 of cask plus supports load to five floor beams. Container designer assumed seven beams.) |

**Trailers**

| | TSI | Light-Weight | FONTAINE |
|---|---|---|---|
| Trailer Type | Flat | Flat | Drop-Frame |
| Torsional Stiffness | 2.105 | 0.438 | 2.750 |
| Center of Gravity | 79.4 | 94.4 | 74.9 |
| Turn Velocity (mph) | 15.04 | 13.8 | 15.5 |
| Rollover Percentage in Accidents | 37% | 68% | 32% |