DROP TESTING OF THE WESTINGHOUSE FRESH NUCLEAR FUEL PACKAGE

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INTRODUCTION

In recent years, the Westinghouse Columbia Fuel Fabrication Facility has been faced with increasing pressure from utilities that wished to take the fuel in their nuclear power plants to higher burnups. To help accommodate this trend, Westinghouse has determined that it needs the ability to increase the enrichment of the fresh fuel it delivers to its customers. One critical step in this process is to certify a new (Type A, fissile) fresh fuel package design that has the capability to transport fuel with a higher enrichment than was previously available. A prototype package was tested in support of the Safety Analysis Report of the Packaging (SARP) (NRC 1991). This paper provides detailed information on those tests and their results.

Westinghouse, with the support of Pacific Nuclear Systems, designed a fresh fuel package that contains two Westinghouse PWR fuel assemblies which are enriched to 5% U^{235}. The new package design had a sufficiently different internal structure as compared to that of previously approved fresh fuel packages (primarily in the area of nuclear poison plates that separate the two assemblies and mechanical support of the fuel assemblies) to warrant the initiation of a test program whose results would support the theoretical analysis presented in the SARP. To maximize the usefulness of the tests, their objectives were (1) to provide sufficient test data on the impact loads experienced by the package in the tests to permit analytic demonstrations that the package is adequate to resist the normal and hypothetical accident conditions of transport, (2) to verify that the package is structurally adequate to survive hypothetical accident condition drops of 9 m while maintaining contents spacing and neutron absorber integrity required for nuclear criticality safety, and (3) to define the hypothetical accident damage to the package as an initial condition for the criticality analysis.

PACKAGE DESIGN

The new Westinghouse modified core component (MCC) packaging is approximately 5.2 m in length and 1 m in diameter and can carry two unirradiated PWR fuel assemblies. The cylindrical packaging is divided longitudinally into two approximately equal parts, making the closure at the midplane of the package (See Fig. 1A). The internal structure is attached to the outer shell by a series of shock mounts which are intended to limit the vibration and shocks under normal

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transport conditions to less than 6 *g* (see Fig. 1B). Since the shock mount system is relatively soft, the system will not significantly affect the velocity of the internal structure on impact. Because of this "softness" of the shock mount system, the outer shell and internal structure were assumed to be decoupled and to act independently in the 9-m drop events.

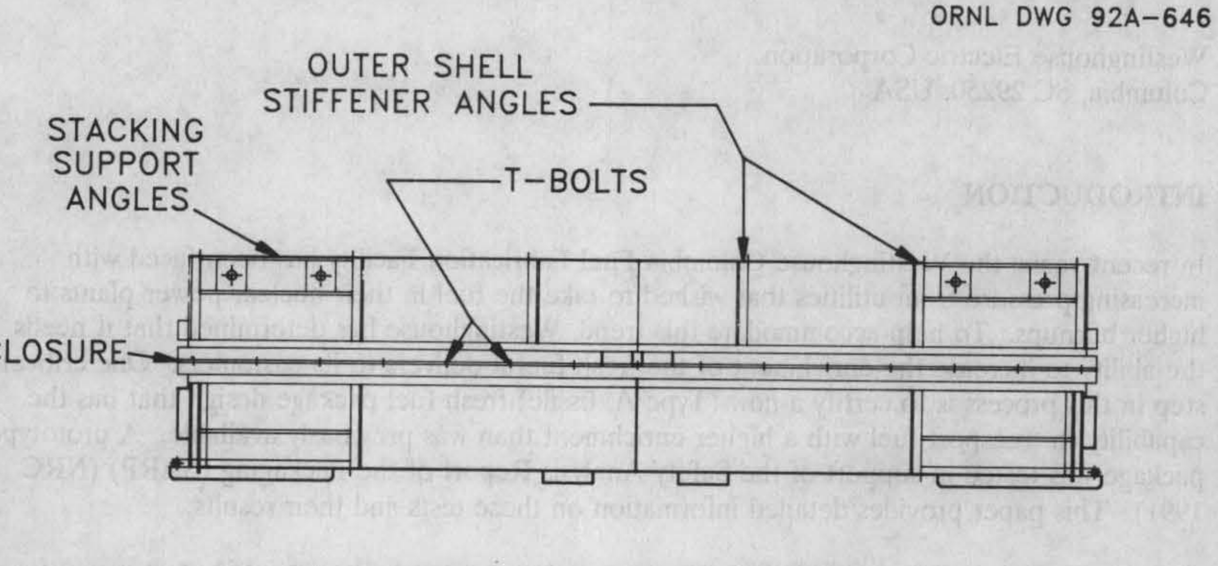

Fig. 1A. The Westinghouse MCC Shipping Package

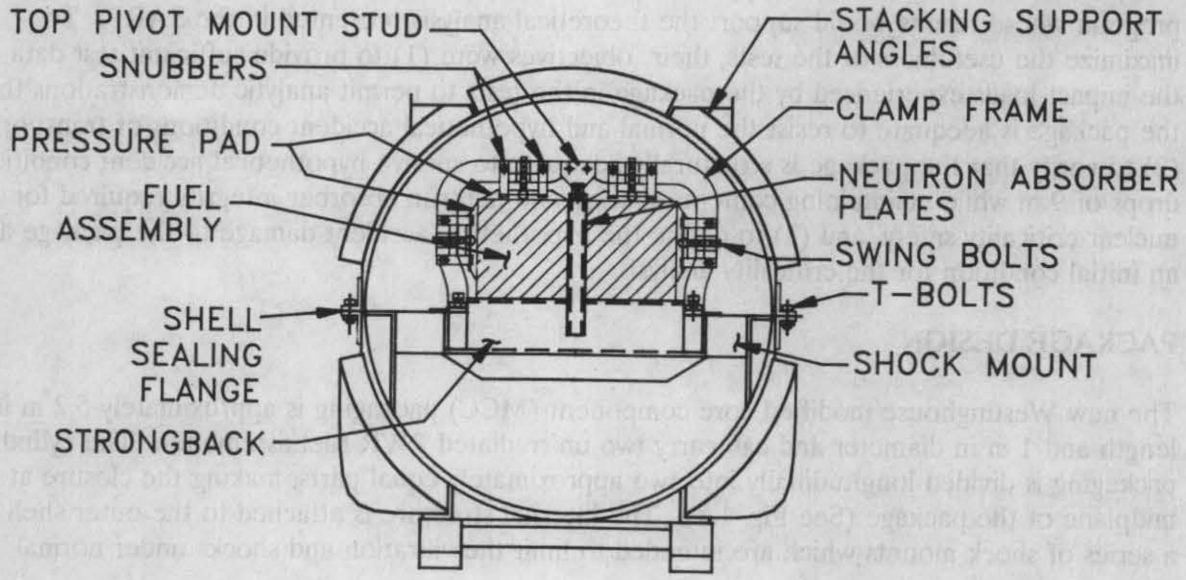

Fig. 1B. A Cross-sectional View of the Westinghouse MCC Shipping Package

The fuel is held in place in a cradle assembly by adjustable fuel element clamping assemblies. The cradle assembly, including a strongback support, is then attached to the outer steel shell by rubber shock mounts. Gadolinium neutron absorber plates are placed between the two fresh fuel assemblies for criticality control. The packaging, loaded with two fuel assemblies, weighs approximately 3420 kg.

In order to test the package design, Westinghouse fabricated three full-size MCC packagings, each capable of containing two dummy fuel assemblies. The dummy assemblies used lead as a surrogate material for the uranium dioxide pellets and weighed approximately 750 kg each.

PRELIMINARY TEST CONSIDERATIONS

A primary goal of the design, and one that became the focus of the packaging tests, was to prevent the system from becoming more reactive under postaccident conditions than was considered acceptable as defined in the SARP. This required that the spacing between fuel assemblies from adjacent packages, when in parallel planes, could not be allowed to be reduced below 20 cm. This is accomplished by ensuring that the fuel assemblies are restrained by the strongback and the clamp frames and that the outer shell of the package remains intact.

Three drop orientations were chosen to demonstrate the container's ability to satisfy these conditions: (1) a horizontal drop onto the package top, (2) a side drop with a slapdown onto the internal clamp frames, and (3) a horizontal side drop onto the package closure. The horizontal drop onto the package top will create an impact load on the clamp frames and their connection points. It also will place significant forces on the snubbers and swing bolts. The slapdown test applied the maximum crush force to the fuel, clamp frames, and connection points in localized areas. The side drop onto the package closure applied the maximum load to the T-bolts which hold the two halves of the outer shell together.

PACKAGE TESTING

The tests were carried out at the Oak Ridge National Laboratory (ORNL) Small Test Facility (STF) in accordance with an approved quality assurance (QA) program and test plan. The STF consists of a reinforced concrete pad with an armor plate impact surface. The pad and armor plate weigh approximately 60 tons but have an effective mass much higher than this since the bulk of the pad rests on a 1-m-diam concrete column which was sunk into bedrock approximately 2 m below grade.

Each test package was equipped with four accelerometers placed in two different locations; two provided a primary electronic signal and two were considered as backup instrumentation. The first pair was located on the strongback that supported the fresh fuel assemblies; the second pair was attached on one end of the outer shell. Data were recorded on a multichannel tape recorder. The signal was digitized to allow filtering of different vibrational frequencies as needed.

A drop test of a prototype package was then conducted, but this initial design did not give the safety margin that Westinghouse wanted for its new containers. Upon examination of the package internals after the test, it was determined that the swing bolts used between the clamping frames and the pressure pads that rest upon the fuel assembly were very high strength and low yield steel, a type not normally used in the older packages that are currently approved to transport fuel having a lower enrichment. The data from this test were used to redesign the connection between the clamping frame and the pressure pad, and the tests were reinitiated.

HORIZONTAL DROP ONTO CONTAINER TOP

The first package tested, using the revised design, was elevated to a height of 9 m and dropped in a horizontal attitude so that it would land on its top (See Fig. 2). The deformation of the top cover was approximately 4 in. It was obvious from the damage that the ends of the package were stiffer than the center, in spite of the stiffening angles that were welded to the package top. The internal structure bottomed out against the top of the container at impact; this was evident because the imprints of the clamp frames on the top shell were apparent.

The fuel restraint system held the fuel assemblies in position. All of the clamp frame connections retained their connectivity to the strongback. There was only a slight deformation of one Unistrut channel at one end of the strongback. The snubbers limited the movement of the pressure pad swing bolts. Their undamaged presence demonstrated that the required spacing would be maintained as long as the outer shell assembly remained intact. The clamp frames did not noticeably deform, and the fuel assemblies crushed approximately 1 to 2 cm. Results of this test therefore indicated that the package design was adequate and that the fuel would be retained by the strongback and clamping frames.

SLAPDOWN ONTO INTERNAL CLAMP FRAMES

A second package was rigged to drop at an angle inclined 30° relative to the horizontal plane and was rotated about its longitudinal axis 135° clockwise to ensure that (1) the impact point would occur on the corner of a fuel assembly; and (2) the package would rotate rapidly and slap down, impacting on the opposite end of the package. The package was then elevated to a height of 9 m and released.

Significant damage occurred to the outside of the package: the initial impact corner caved in approximately 15 cm, and the slapdown corner deformed approximately 18 cm. The stacking support angle was completely crushed and flattened on both ends. The internal structure impacted the outer shell and punched several holes in each of the corners.

Most of the kinetic energy of the initial impact was absorbed by deforming the top shell. The fuel restraining bolts on the end clamp frame deformed significantly, and one connecting pin was sheared; however, the end clamp frame itself was only slightly deformed. The fuel assembly closest to the initial impact point was crushed very little (See Fig. 3).

As expected, the damage on the slapdown end was more significant. Three clamp frames were deformed inwardly with most of the damage occurring on those closest to the slapdown end. Although the bottom support structure punched through the outer shell and struck the impact surface, the fuel experienced a relatively high *g* loading but only limited deformation. Due to the deformation of several clamp frames, the top pivot-mount stud nuts partially pulled out of the Unistrut channel. This is not of concern since the fuel assemblies remained restrained, being held in place by other clamp frames. The fuel assemblies under the pressure pads were crushed approximately 1-2 cm.

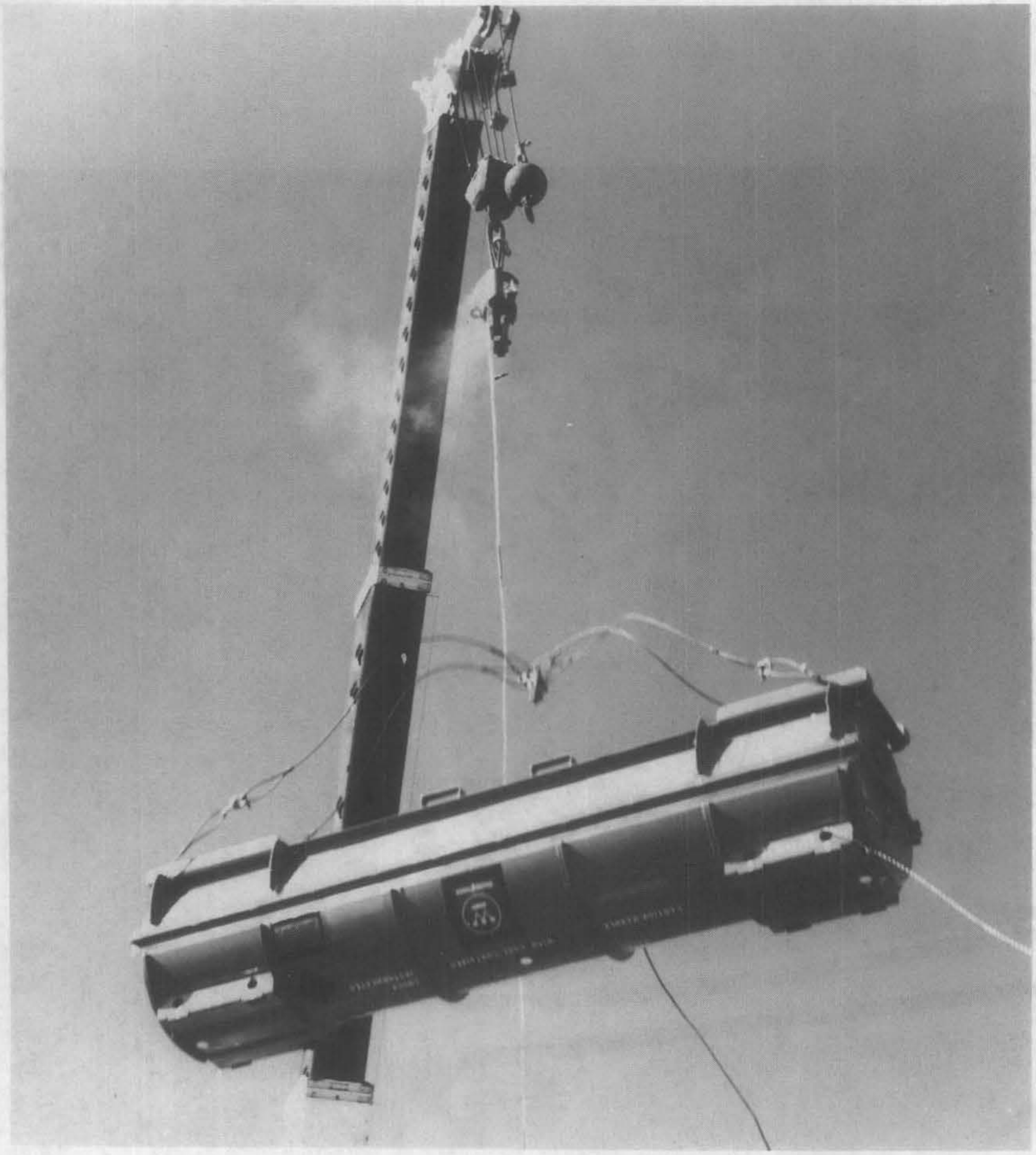

Fig. 2. Horizontal Drop onto Container Top

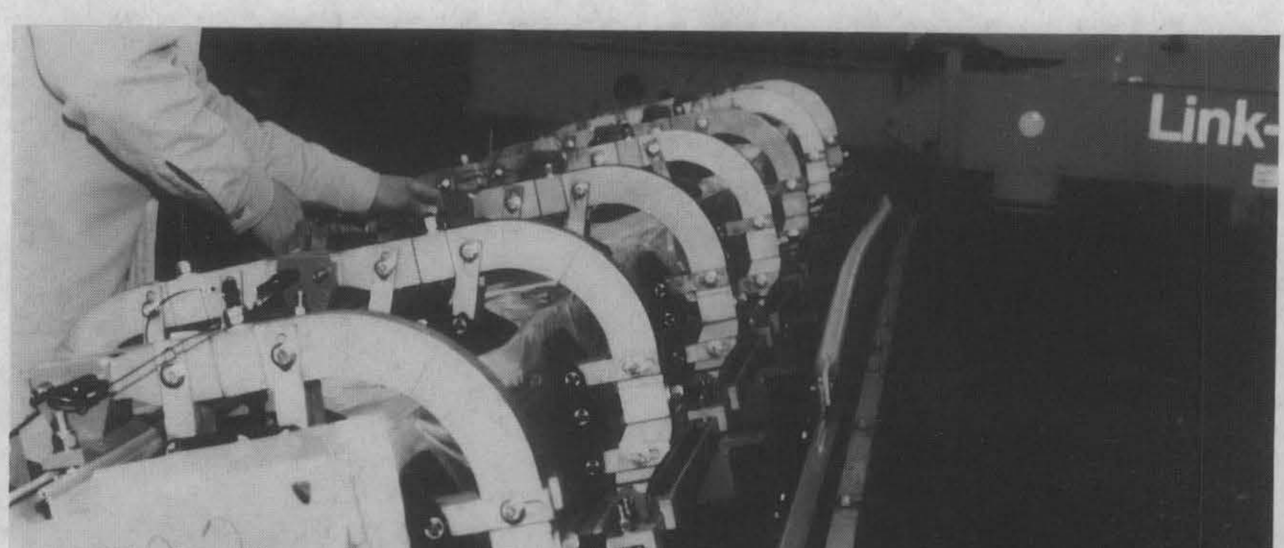

Fig. 3. Results of Slapdown Drop onto Internal Clamp Frames

HORIZONTAL DROP ONTO THE PACKAGE CLOSURE

In this test, a third package was rigged in a horizontal position such that the impact would occur along the closure seam that holds the top and bottom of the package together. This was done to demonstrate the adequacy of the closure T-bolts that fasten the top onto the bottom of the package.

Fifteen of the 30 T-bolts either pulled through the shell sealing flange or failed in tension. None of the T-bolts failed in shear; nor did any of the six guide pins, which have a tighter tolerance than the T-bolts. The location of the T-bolt failures varied, apparently depending upon the construction of the container. However, on the impact side, six bolts failed, and the majority of these failures were in the center section where the shell has the minimum amount of reinforcement. In addition, the outer (bottom) shell, where the internal shock mount bracket is fastened, deformed and applied a high bending moment in the closure flange area. This prying action was resisted by the T-bolts until failure occurred. However, this condition did not occur toward the ends of the package where the major reinforcement of the shell exists and which would resist the bending moment.

The remaining T-bolts failed on the ends and toward the ends of the nonimpacted side. These failures were the result of stiff ends, and reinforcement in these locations, which transmitted the separation load caused by the weight of the shell and internals, pushing the shell apart. The moment was resisted by the bolts on the far side of the container. This behavior ensures that there is a large margin of safety against having the outer shell assembly fail in such a manner that the internal structure will separate from the outer shell.

The internal structure impacted initially on the shock mounts and then rotated to spread the load between the shock mounts and the clamp frames contacting the external shell. The load on the shock mounts crushed the mounting bracket such that the connecting bolts and frames impacted into the outer shell (See Fig. 4).

The impact on the frames, with the subsequent load transmittal to the center wall, caused some yielding in the Unistrut pivot mount connections to the center wall. All of the clamp frames remained connected to their adjacent frames so that restraint of the fuel assemblies was maintained. The majority of the damage occurred in the center section of the outer container where the deformation was greatest, allowing the largest deformation of the package internals. The center clamp frame pried its lower pivot mount connection out of the Unistrut channel. However, this failure does not prevent the package from fulfilling its requirements. There was a small amount of crush to the fuel assemblies of about 1 cm.

SUMMARY

The packages performed well in all drop tests. In general, the damage/deformation was less than was expected based on calculations provided in the SARP. The clamp frames' geometry was preserved, and the overall spacing between the fuel and outer shell was maintained. Sufficient T-bolts, which attach the top outer shell to the bottom shell, survived the drop to ensure that the outer shell of the package would not be separated from the fuel assemblies and the internal structure.

In all cases, very little global damage occurred to the fuel assemblies or the internal structure. The center wall between the two fuel assemblies deformed very little, thus ensuring that the gadolinium plates would remain intact and functional.

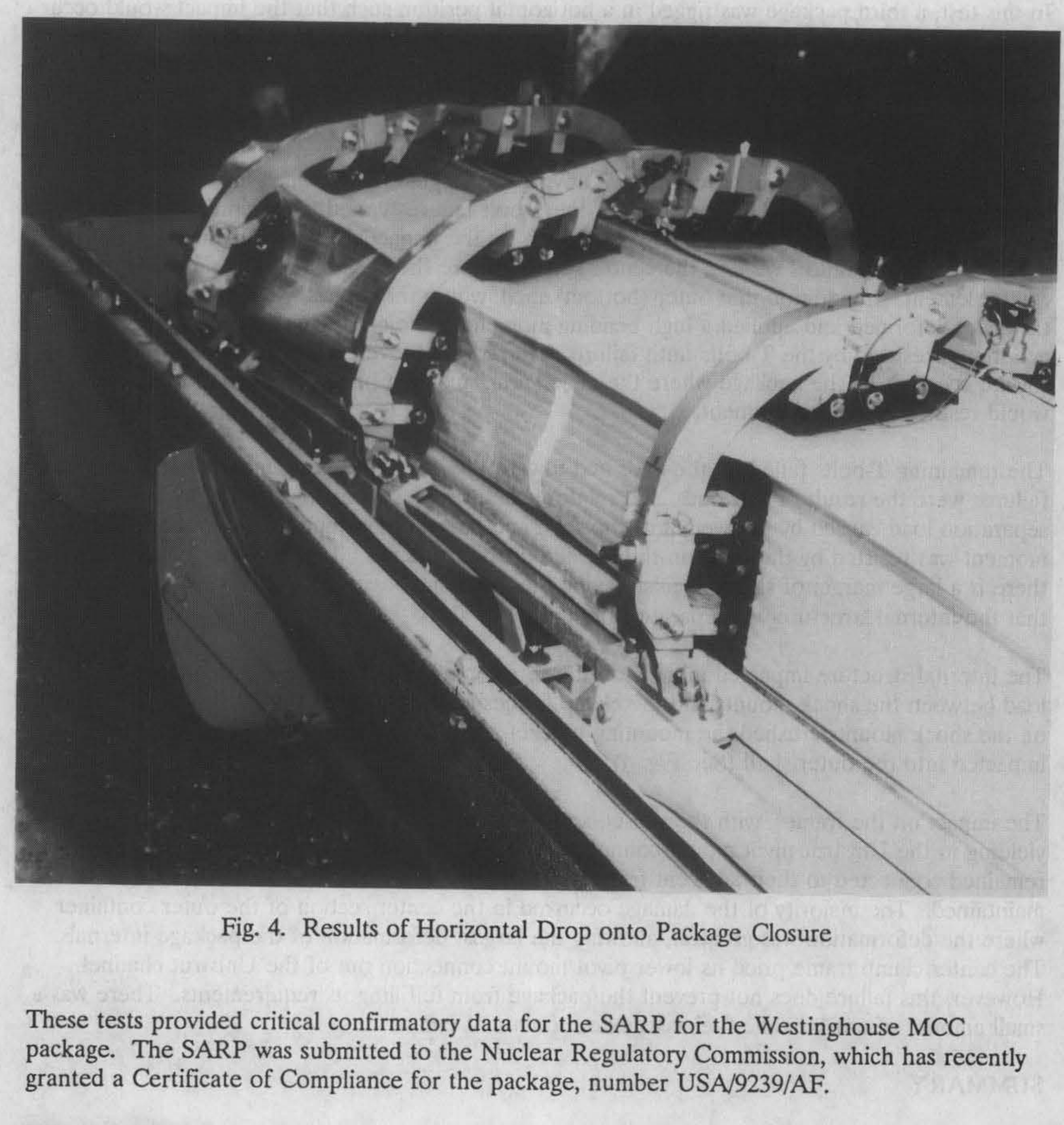

Fig. 4. Results of Horizontal Drop onto Package Closure

These tests provided critical confirmatory data for the SARP for the Westinghouse MCC package. The SARP was submitted to the Nuclear Regulatory Commission, which has recently granted a Certificate of Compliance for the package, number USA/9239/AF.

REFERENCES

NRC Docket No. 71-9239, 1991