Drop Tests of a Cubic DCI Container for Radioactive Wastes

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Test Requirements for Radioactive Waste Disposal Packages

Packagings for non-heat-generating radioactive wastes to be disposed of in the planned repository in the F.R.G. - the former "Konrad" iron ore mine - must fulfill defined requirements to ensure safety in operation and in case of incidents (Bundesamt für Strahlenschutz, 1991). For a certain category of packagings with a higher level of radioactive inventory - the so-called waste container class II - a drop from a height of 3 m in the transfer/buffer hall and a drop from a height of 5 m in an emplacement room inside the repository had been assumed in the safety analyses (Illi, 1987; Berg et al., 1987). Although the safety analyses including the accident analyses are not yet confirmed by the state authority and their experts, conservative test requirements had been established to start immediately with the waste package design qualification (Mertens et al., 1990). Design evaluation and testing will be performed by BAM Berlin. The tests described in this paper, had been carried out by BAM on the basis of a contract with the local competent authority for the radioactive waste interim storage at Gorleben, the Safety Inspectorate Lüneburg. The design evaluation procedure in the future will be based on a contract between BAM and the Bundesamt für Strahlenschutz, Salzgitter (Federal Office for Radiation Protection), which is the institution responsible for the repository construction and operation in Germany. GNS, Essen, is charged by the industry for waste conditioning, including the construction of the waste packagings.

Drop Test Conditions

The test specimen was a "DCI container Type VI" taken from the serial production of the Siempelkamp foundry, which manufactures these containers for GNS. The container consists of a monolithic body of cubic shape with a wall thickness of 150 mm (240 mm in the lid side), a thick internal DCI lid and a thin

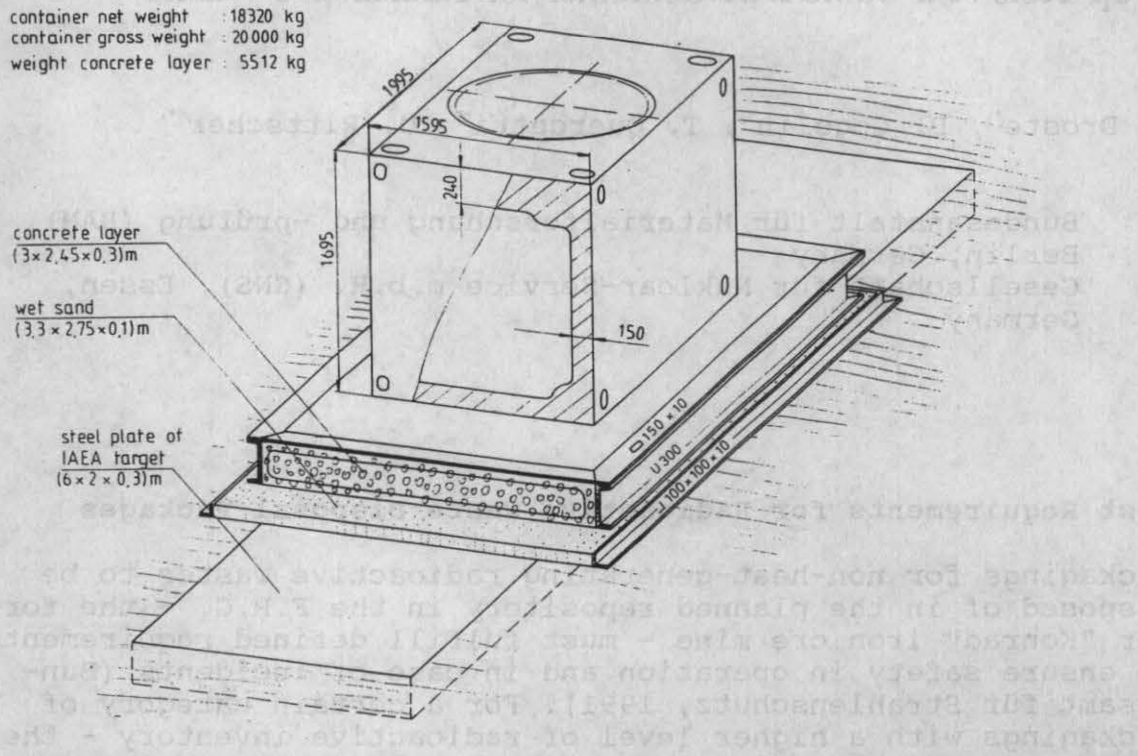

Figure 1: DCI Container and Concrete Target Used for the Flat Drops

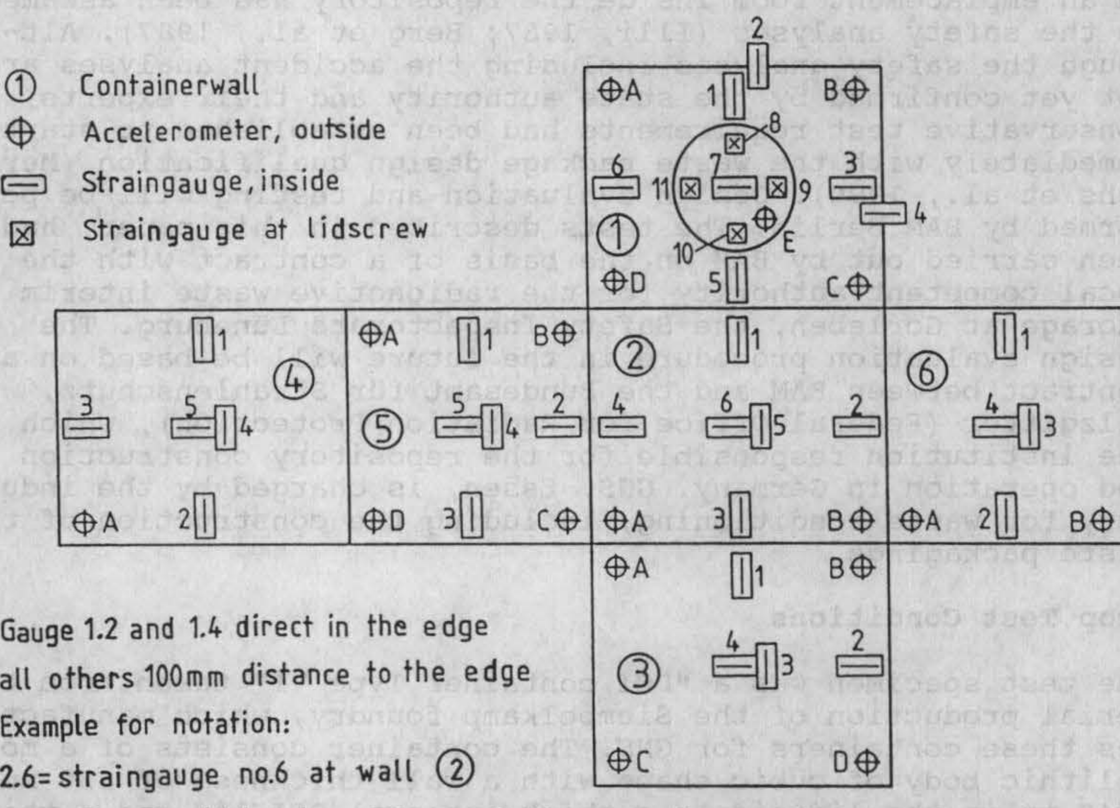

Figure 2: Positioning Plan of the Accelerometers and Strain Gauges

external mild steel lid (Figure 1). The lids are bolted (stainless steel bolts A2-70, 24 bolts M 36 x 110 for the thick lid) and sealed with elastomere gaskets. The outer container demensions are: 1695 mm (height) x 1595 mm (width) x 1995 mm (length). The container tare weight is 18,320 kg, with its loading (for the tests simulated by pumice) the gross weight ist 20,000 kg. For handling purposes the container has in-casted ISO-corner fittings.

The drop test target should simulate the rigidity of the real underground, that is the geologic formation inside the repository emplacement room. Considering the results of the geological research reports, our BAM experts for underground constructions derived a "B 35" concrete quality to meet this requirement. For the tests we used a reinforced concrete layer (B 45 quality) of 300 mm thickness, framed by U-shaped mild steel profiles (Figure 1). For each test, a new concrete plate with an interspace layer of wet sand was positioned above the unyielding target of the BAM 1000 t-drop test facility in Lehre. This target was usefull for the flat drop test positions onto the container bottom and onto the small side. When the container was dropped onto its edge, this concrete layer broke into two fragments that were thrown away. We therefore had to construct another basement design for that drop position . For this test we removed the steel plate from the top of the 1000 t-IAEA target and embedded the framed concrete plate into the big concrete block. Additionally we fixed the concrete plate with two U-profiles (parallel to the edge line), connected with three trough bolts each. This target construction ensured that no horizontal shifting of fragments occurred in the test onto the small container edge.
The container instrumentation with accelerometers and strain gauges at the inner surface of the container walls and at selected lid screws is shown in Figure 2.

Test Results

- 5 m Drop flat onto the bottom

The deceleration values (Figure 3) show the characteristics of a short and hard impact. The primary impact has a duration of 4.5 ms; the peak value is 2260 g. The strain values located in the middle of wall No. 6 (a wall perpendicular to the bottom) show an oscillation around a positive value (tension) in the first 2.5 ms and afterwards a spontaneous switch to negative values (compression) (see Figure 4). It can be concluded that this buckling of the wall led to high tension stresses (near to yield strength) at the wall's outer surface. Strain gauge 4.2 (located 100 mm above the inside bottom edge) in Figure 4 also demonstrates this behaviour, with high compression values due to the wall's buckling inside within the first 4.5 ms and an oscillation afterwards with a high amplitude around zero.

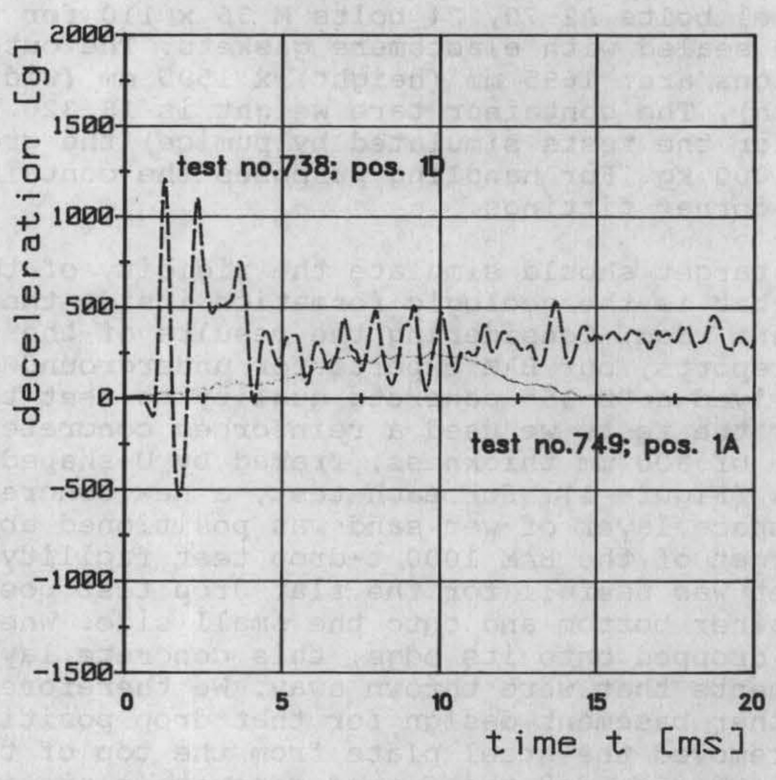

Figure 3: Deceleration Values for Flat Bottom Drop (738) and Small Edge Drop (749)

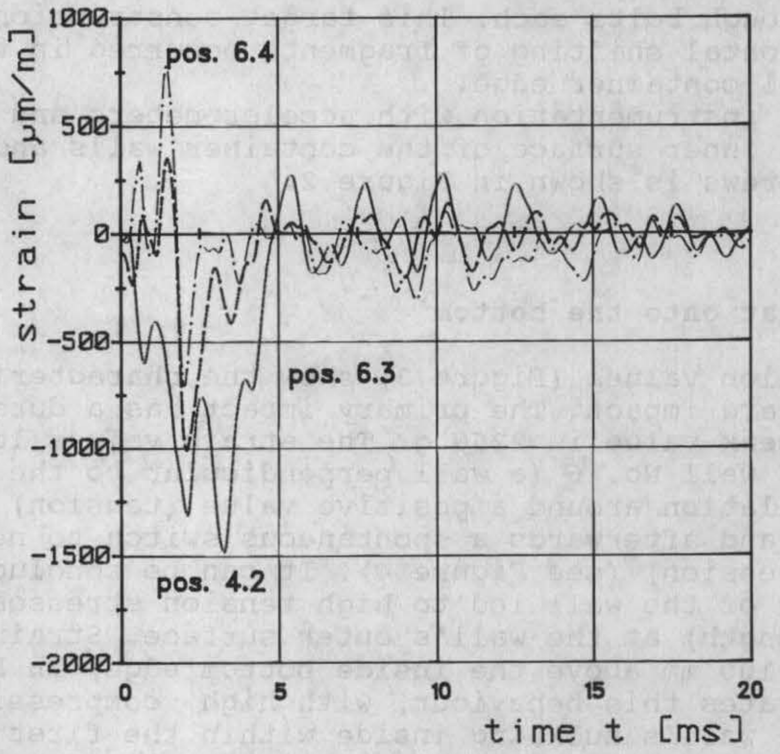

Figure 4: Selected Wall Strain Values in Flat Bottom Drop

Figure 5 shows the strain measured at 3 screws of the thick lid; shown are the changes compared to the pre-stressed state before the test. We see no significant changes within the period of the primary impact (4.5 ms), but after this time a positive impulse to tension stresses up to a plastic deformation

(screw pos. 1.11). The standard Helium leakage rate of the big lid after the test was < 1.2×10^{-7} mbar l/s.

- 5 m Drop flat onto a small container side

The container was dropped onto wall No. 6 (Figure 6). The impact characteristic and container wall behavior was quite similar to the drop test mentioned before. The primary impact was within 5 ms, the deceleration peak value 1210 g. Strain values at the impacted wall No. 6 show high tension values (Figure 7). The strain gauge 1.4 located directly in the hollow groove between walls No. 1 and 6 shows clearly that after the impact (e.g. after 7 ms) an oscillation ($f = 781\ s^{-1}$) with increasing amplitude up to $\pm$ 1200 μm/m occured. The big lid's leakage rate after the test was $\leq 6.3 \times 10^{-8}$ mbar/s.

- 5 m Drop onto a small container edge

In the flat drop positions the container penetrated only approx. 3 mm into the concrete plate. In this drop test onto the edge between walls No. 2 and 6 (lid down), the container edge penetrated 50 to 70 mm into the concrete plate. But the horizontal movement of concrete was prevented.

The primary impact, relatively "soft" with a peak deceleration value of 250 g (Figure 3), had a duration of 15 ms. Strain measurements at the container walls (Figure 8) and at lid screws (Figure 9) show significant lower tension stresses than in case of the flat drops.

The leakage rate of the lid after the test was < 5×10^{-6} mbarl/s.

Conclusions

The container remained its integrity and tightness after 3 drop tests from a height of 5 m onto a concrete target simulating the underground formation of the planned German "Konrad" repository. The interpretation of the strain measurements show high tension stresses in the ductile cast iron walls due to oscillations of container walls after an impact onto a flat side. These stresses have to be investigated in more detail, and the DCI behaviour under these stress levels has to be evaluated considering a fracture toughnesse analysis. To prevent undue plastic deformations of screws, the use of steel with a higher yield strength has to be taken into account.

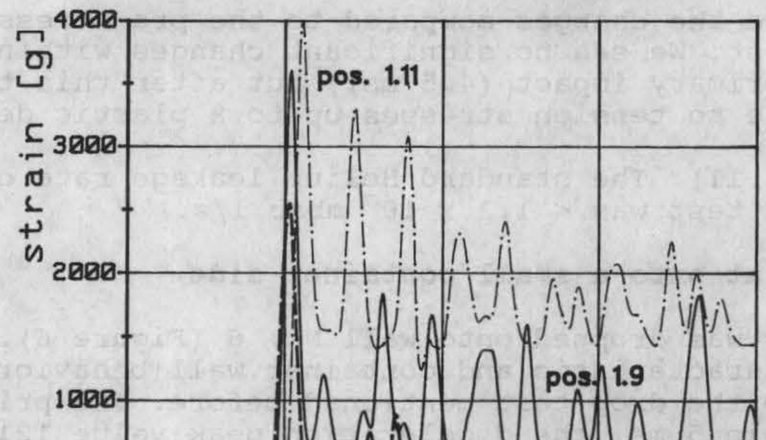

Figure 5: Screw Strain Values in Flat Bottom Drop

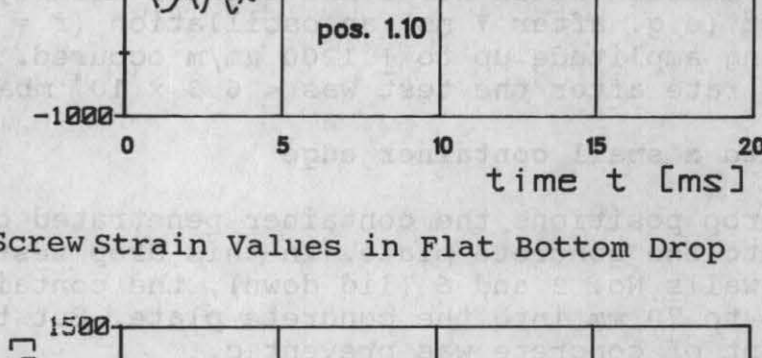

Figure 7: Wall Strain Values in Flat Small Side Drop

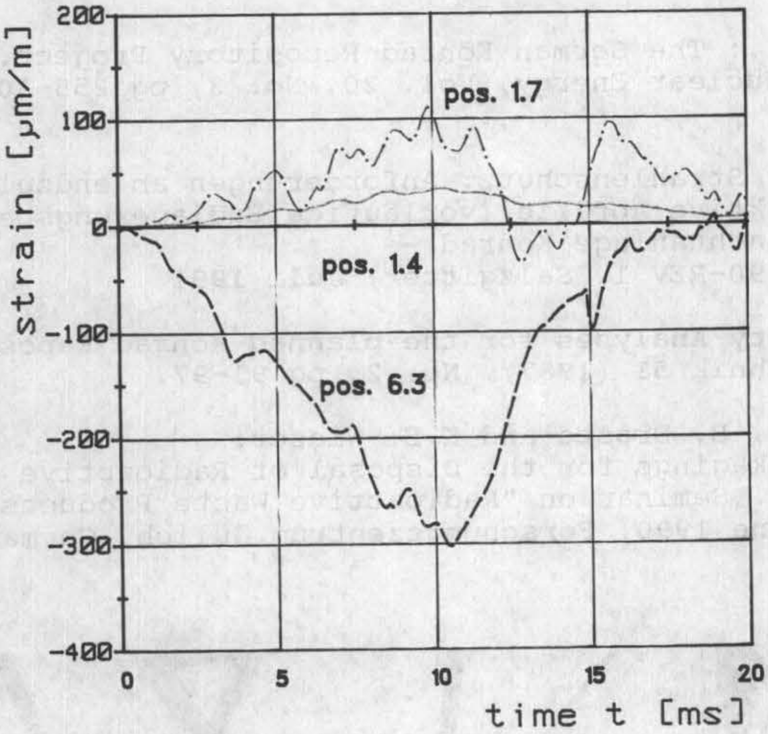

Figure 8: Wall Strain Values in Small Edge Drop

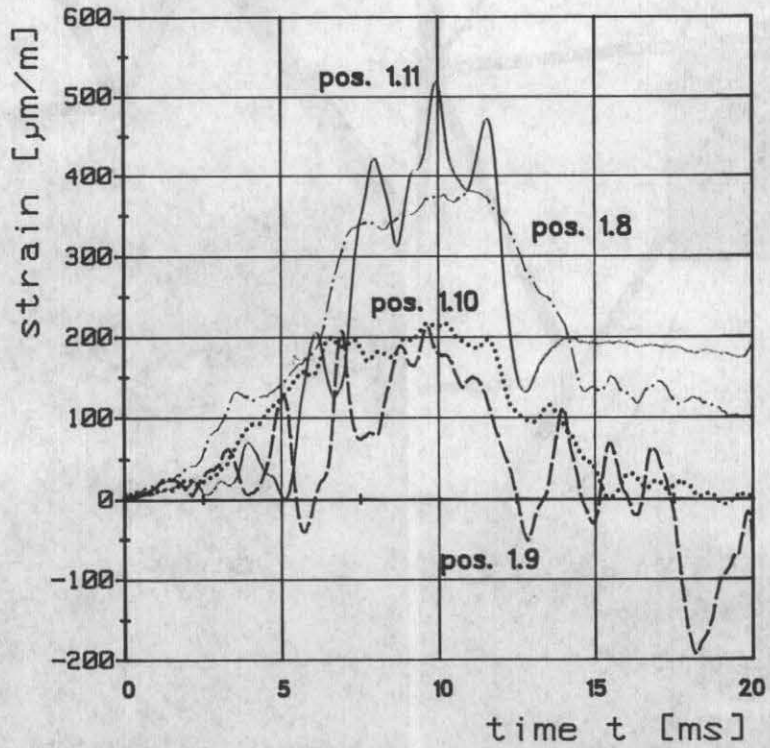

Figure 9: Screw Strain Values in Small Edge Drop

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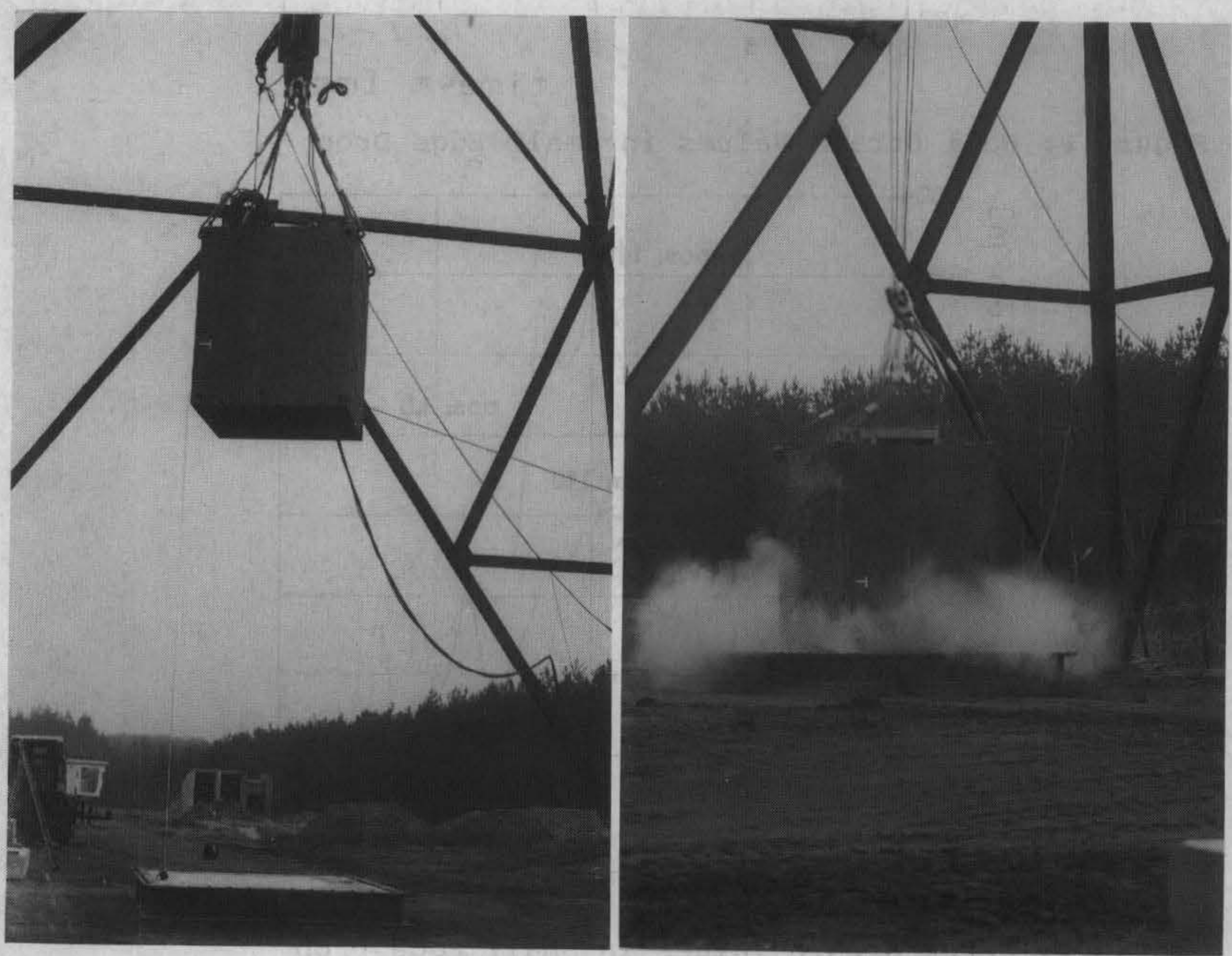

Figure 6: 5 m Drop Onto the Small Container Side