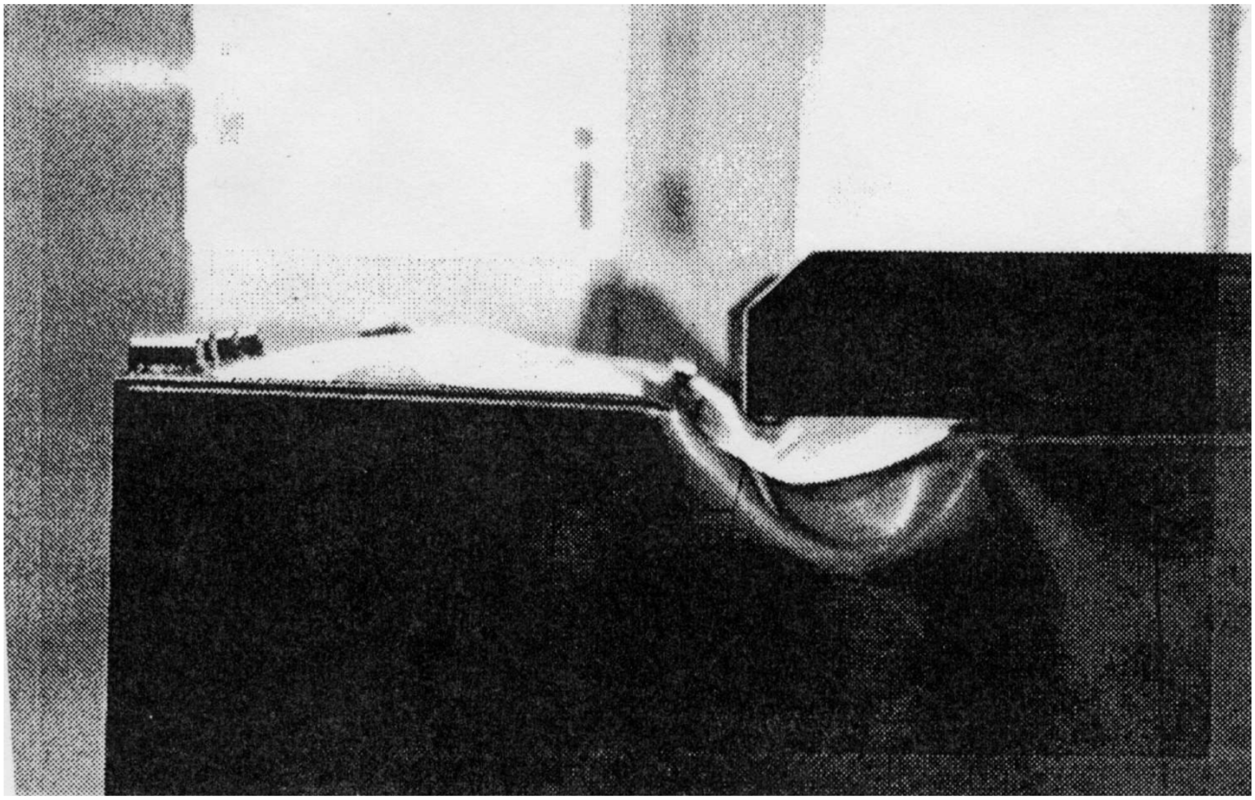

Figure 2-47 CTU 1J 9-m Vertical End Drop: Close-up Side View of Bottom Damage

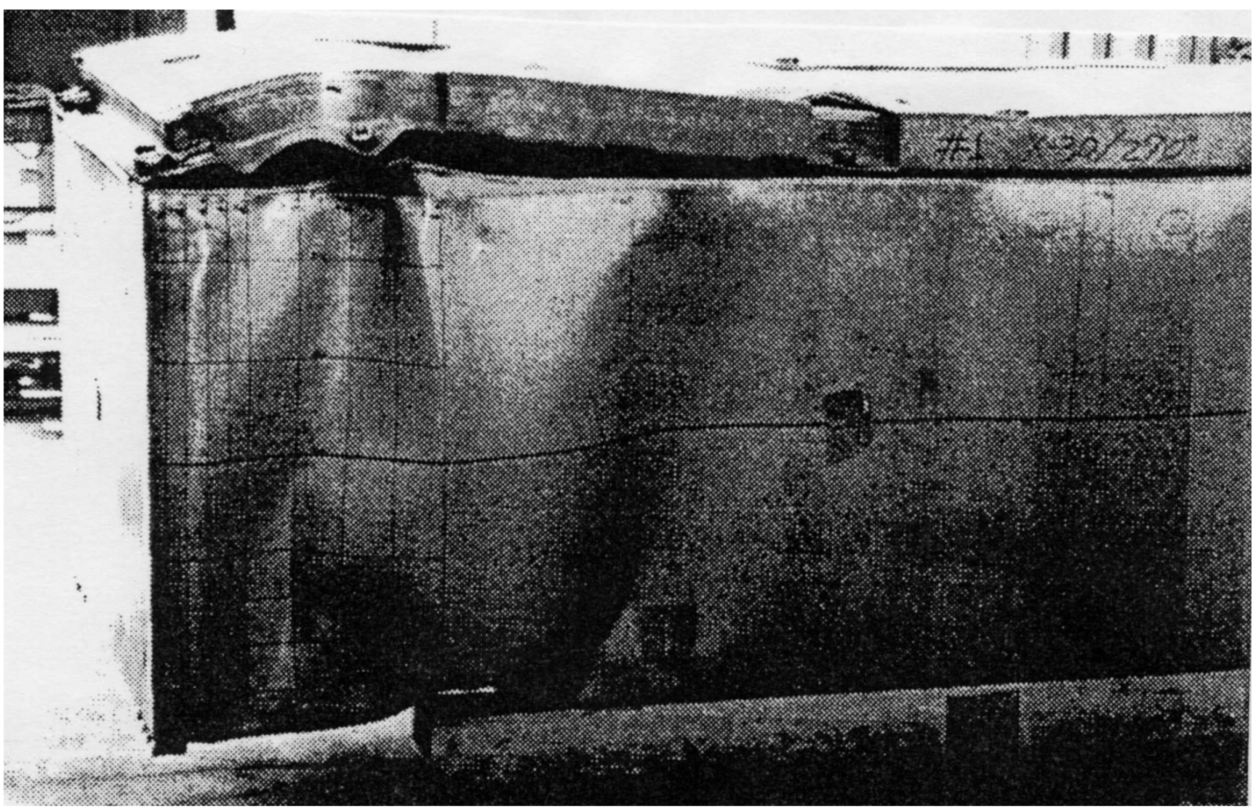

Figure 2-48 CTU 1J 9-m Vertical End Drop: Overall View of Damage

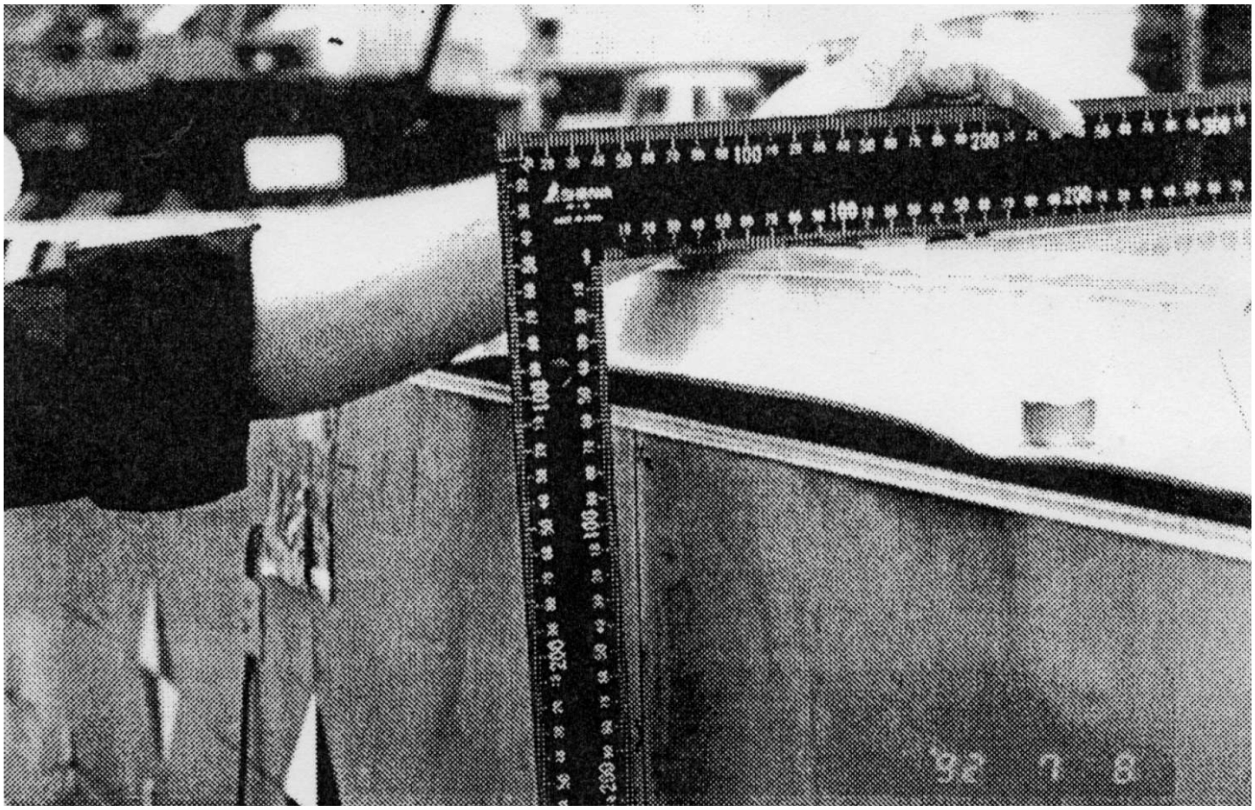

Figure 2-49 CTU 2J 9-m Horizontal Free Drop: Close-up Side View of Damage

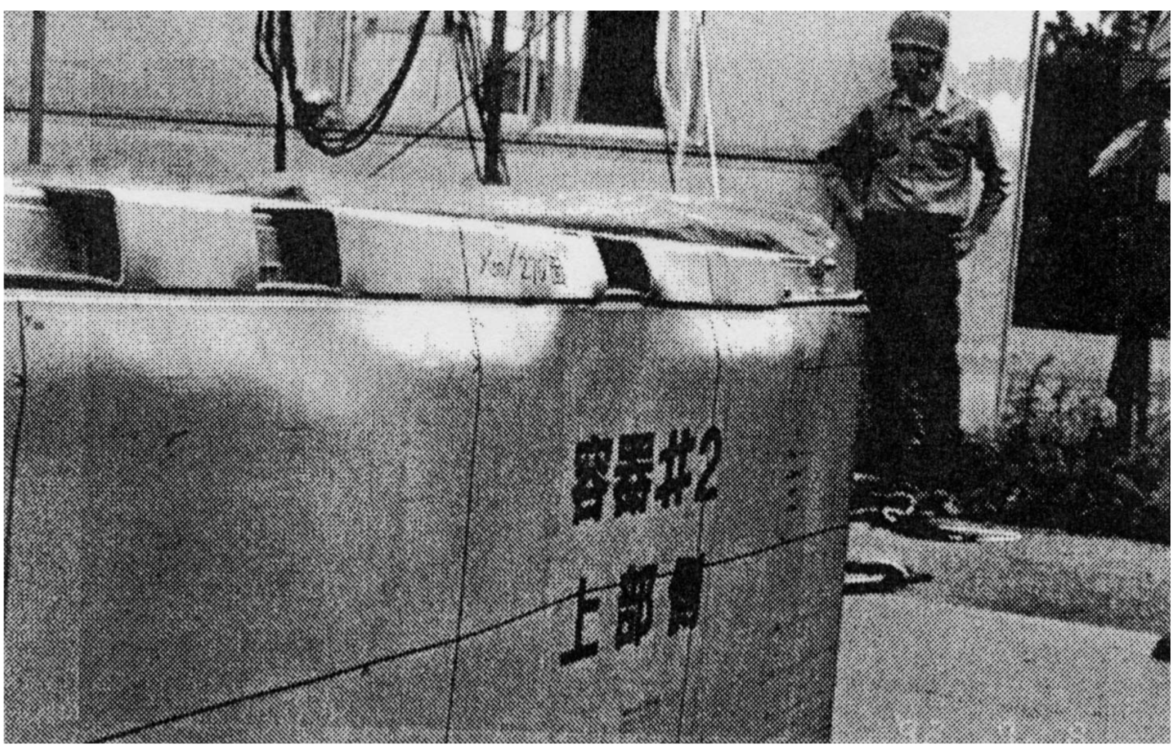

Figure 2-50 CTU 2J 9-m Horizontal Free Drop: Overall Side View of Damage

2.12.3 Outer Container Gasket Sealing Capability

The outer container for the RAJ-II packaging utilizes a 5 mm thick × 40 mm wide × 11,360 mm long, 50 shore durometer, solid natural rubber gasket. As shown in Appendix 1.4.1, Packaging General Arrangement Drawings, the gasket is attached to the flange of the outer container lid. The outer container lid is secured to the outer container body by twenty-four (24) M14 × 2, Type 304 stainless steel bolts, which are tightened to "wrench tight or as defined in user procedures". Since a specific tightening torque is not specified, the maximum bolt tension will be based on the minimum yield strength of the stainless steel.

The maximum force, F_b, in each lid bolt will be:

$$F_b = S_y (A_t)$$

where: S_y = Minimum yield strength = 206.8 MPa (30.0 ksi) (Ref. Table 2-2)

A_t = Tensile area for M14 × 2 bolt = 115 mm^2 (0.1783 in^2)

Substituting these values into the above equation yields a bolt force of 23,782 N (5,349 lb_f). The total compressive force applied to the gasket, F_{gasket}, is then:

$$F_{gasket} = (24)F_b = (24)(23{,}782) = 570{,}768 \text{ N } (128{,}376 \text{ lb}_f)$$

For the applied bolt force, the gasket compressive area, A_{gasket}, is 40 × 11,360 = 454,400 mm^2 (704.3 in^2). Conservatively neglecting any deflection of the 4-mm thick lid flange between the lid bolts, the resultant compressive stress on the gasket is then:

$$\sigma_{gasket} = \frac{570{,}768}{454{,}400} = 1.256 \text{ MPa } (182 \text{ psi})$$

The shape factor, s, for the 5 × 40 gasket is:

$$s = \frac{\text{One Load Area}}{\text{Total Free Area}} = \frac{\text{Width}}{2(\text{thickness})} = \frac{40}{10} = 4.0$$

From Figure 5-12 of Handbook of Molded and Extruded Rubber[a], the percent compressive deflection of the 50-durometer gasket with s = 4.0 at 182 psi compressive stress is approximately 3%, or 0.15 mm (0.006 in), which is minimal.

To determine whether the gasket is compressed with the applied bolt force, the compression modulus and the linear spring rate for the gasket is computed. Equation 3-7 of Handbook of Molded and Extruded Rubber, the linear spring rate, K_L, for the rubber gasket is:

$$K_L = \frac{E_c(A)}{h}$$

where: E_c = Compression modulus

A = Compression area of gasket = 454,400 mm^2 (704.3 in^2)

h = height of gasket = 5 mm (0.197 in)

The compression modulus is extracted from Figure 5-20 of the Handbook of Molded and Extruded Rubber for a shape factor "s" of 4.0 and an approximate compression of 3% for the 50 durometer gasket. From this figure, the compression modulus is interpolated to be 6,912 psi (47.7 MPa). The linear spring rate of the gasket is then:

[a] *Handbook of Molded and Extruded Rubber, Third Edition*, Goodyear Tire & Rubber Company.

$$K_L = \frac{6,912(704)}{0.197} = 24.7 \times 10^6 \text{ lb}_f/\text{in } (4.33 \times 10^6 \text{ N/mm})$$

To compress the gasket 0.15 mm (0.006 in), the required force in the bolts is:

$$24F_{bolt} = K_L \Delta = 24.7 \times 10^6 (0.006) = 148,200 \text{ lb}_f \text{ } (659,266 \text{ N})$$

$$\Rightarrow F_{bolt} = 6,175 \text{ lb}_f \text{ } (27,648 \text{ N})$$

Since the resultant bolt force required to compress the gasket 3% is greater than the yield strength of the lid bolts, the gasket will not be compressed to the estimated 3% compression. To determine the estimated gasket compression with the maximum lid bolt force at yield strength (23,782 N [5,349 lb_f]), the linear spring rate will be computed for zero compression and then compared to the applied maximum force. From Figure 5-20 of the Handbook of Molded and Extruded Rubber for a shape factor "s" of 4.0, the compression modulus at zero compression will be:

$$E_c = 9,000(0.75) = 6,750 \text{ psi } (46.5 \text{ MPa})$$

For zero compression and this compression modulus, the linear spring rate is:

$$K_L = \frac{6,750(704)}{0.197} = 24.1 \times 10^6 \text{ lb}_f/\text{in } (4.23 \times 10^6 \text{ N/mm})$$

The resultant deformation of the gasket for this spring rate with the maximum bolt force is:

$$\Delta_{gasket} = \frac{24(F_{bolt})}{K_L} = \frac{24(23,782)}{4.23 \times 10^6} = 0.135 \text{ mm } (0.005 \text{ in})$$

This deformation is approximately 2.7% compression of the gasket. Prototypic seal testing in support of the TRUPACT-II package[b] has demonstrated that a pressure seal requires a minimum of 10% – 12% compression. Section 3.6, *Squeeze*, of the Parker O-ring Handbook[c] states that "*The minimum squeeze for all seals, regardless of cross-section should be about 0.2 mm (0.007 inches). The reason is that with a very light squeeze almost all elastomers quickly take 100% compression set.* " Based on these test results and the recommendations of Parker, the outer lid gasket will not form a pressure retaining seal.

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[b] U. S. Department of Energy (DOE), *Safety Analysis Report for the TRUPACT-II Shipping Package*, USNRC Certificate of Compliance 71-9218, U.S Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico.

[c] ORD 5700A/US, *Parker O-ring Handbook*, 2001, Parker Hannifin Corporation, Lexington, KY.