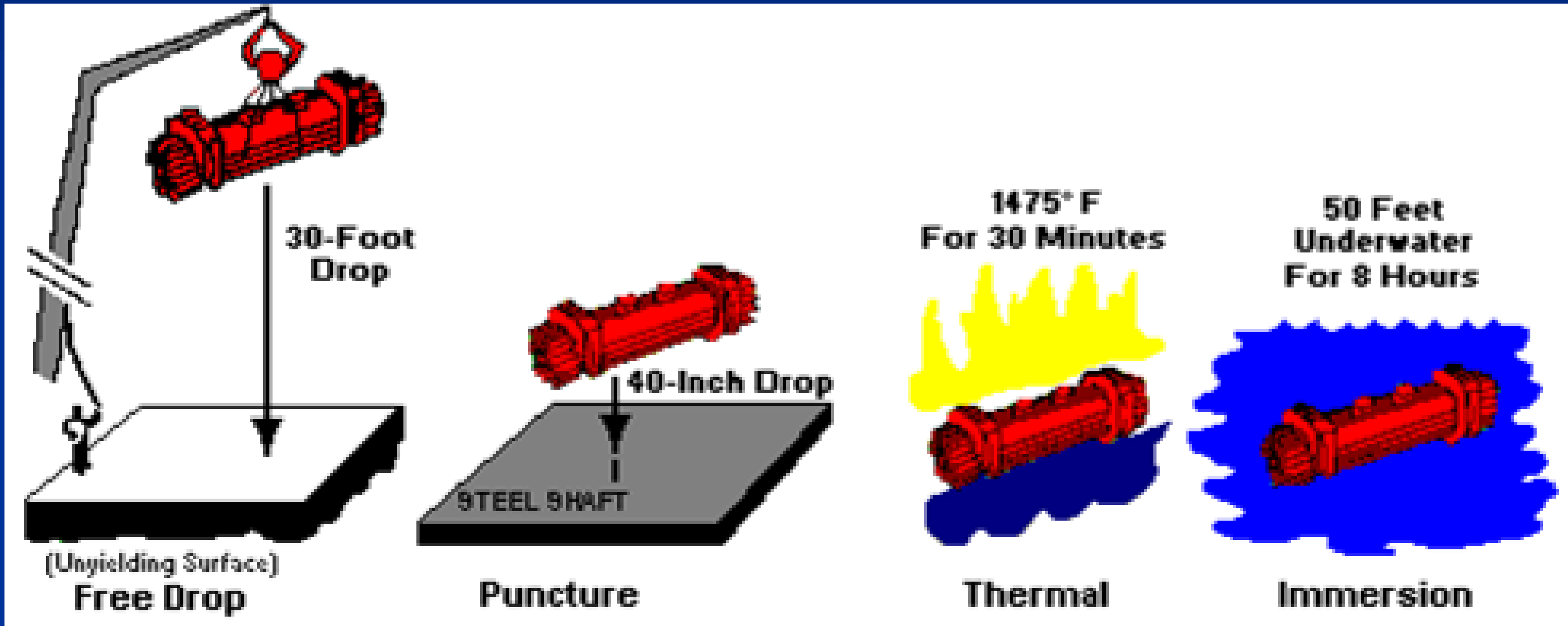
Type B Standards
Do they address real world accidents?



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Why Type B Standards ?

- Transportation Accidents Happen.
  - Practically all accidents are characterized by Impact, Fires, Puncture and Submersion.
- Goal is to protect humans from direct radiation exposure, and inhalation and/or ingestion hazardous.

Development of Type B Standards

- IAEA 1961 - "maximum credible accident relevant to the mode of transport."
- IAEA 1961 - ***Notes on Certain Aspects of the Regulations*** recommends "maximum credible accident as represented by a drop of 30 ft. on to a hard surface, followed by a furnace test at a temperature of 800°C for a half hour.

Development of Type B Standards (continued)

- IAEA 1964 – adoption of 30 foot drop test onto an "unyielding surface", and 30 minute thermal test at 800° C.
- Similar US regulations date from about the same time.
- US 1970's- SANDIA Crash Tests.
- US 1978 – Battelle risk assessment for Truck Shipment of SNF.

Development of Type B Standards (continued)

- UK 1985 – Operation "Smash Hit".
- USA 1987 – "Modal Study" relates Type B spent fuel casks to real world accidents.
- USA 2000 – Reexamination of Spent Fuel Shipment Risk Estimates. (NUREG-6672).

Type B Standards

- are intended to bound the types of cask damage that could be experienced in severe accidents.
- do not attempt to mimic severe accident scenarios.
- provide reproducible results.

Type B Standards (continued)

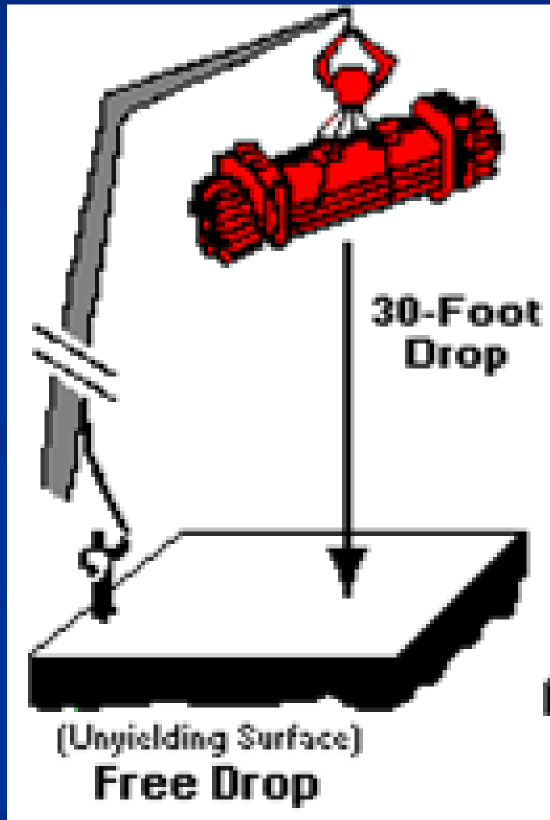
- Thirty foot drop, puncture and fire test are carried out in sequence.
- Stringent acceptance criteria for release, radiation level and criticality safety.

Impact Test

- Drop height defines the cask's potential and kinetic energies.
- Unyielding surface means that the cask's total kinetic energy is absorbed by the cask.
- In a drop test, a cask's potential energy is converted into kinetic energy.

$$mgh \Rightarrow \frac{1}{2} mv^2.$$

- Final Velocity = $\sqrt{gh/2}$ = 30 mph.



Real Impacts

- In real impacts the kinetic energy would be absorbed by both the cask and the impacted object.
- Harder objects would absorb less energy and suffer less deformation, softer objects would absorb more energy suffer greater deformation.
- Some energy is loss to after impact kinetic energy, or conversion to heat, etc.

Unyielding Surface

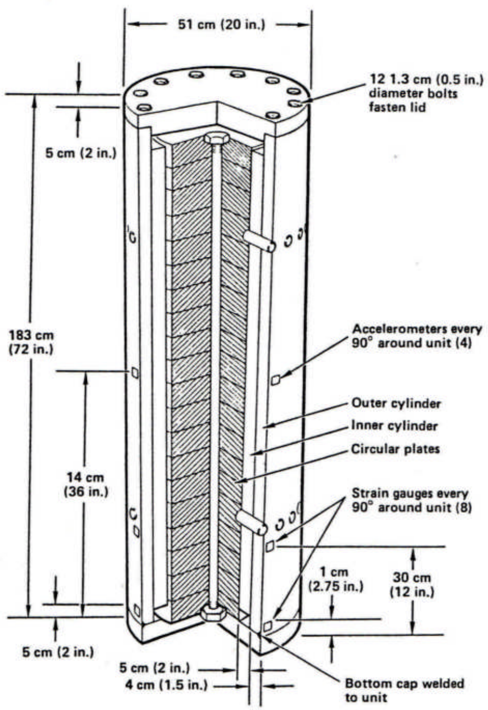


FIG. 1. Target hardness test unit.

TABLE I. TARGET HARDNESS TEST RESULTS

Target	Impact velocity m/s (ft/s)	Unit penetration cm (in)	Maximum compressive strain (microstrains)
Soil	13 (44)	48 (19)	90
	20 (66)	64 (25)	600
	27 (88)	86 (34)	900
Concrete runway	13 (44)	0.6 (0.25)	500
	20 (66)	10 (4)	1500
Concrete highway	13 (44)	10 (4)	400
	27 (88)	48 (19)	1500
Unyielding target	13 (44)	0	3500[a]

[a] Final strain in tension.

Taken from: **Target Hardness Comparisons with the IAEA Unyielding Surface by A. Gonzales, J. Pierce, SANDIA National Laboratories.**

Thought Experiment

Unyielding Surface

- 100 ton cask dropped 30 ft on to an unyielding surface
- Total energy absorbed = 6,000,000 ft-lbs

Yielding Surface

- 100 ton cask dropped 30 ft on to soil.
- 90% or 5,400,000 ft-lbs absorbed by soil.
- 10% or 600,000 ft-lbs absorbed by cask.

Thought Experiment (continued)

- To get cask to absorb 6,000,000 ft-lbs, you need 60,000,000 ft-lbs of initial kinetic energy.
- The equivalent velocity would be:

$$V_e = \sqrt{gh/2} = 95 \text{ mph}$$

- The equivalent velocity for hard concrete that absorbs 85% of the energy would be 70 mph.

Conservatisms

- Some energy is lost to post impact kinetic energies of cask or impacted object.
- Some energy is absorbed by conveyance.
- Casks are designed with impact limiters to absorb most of the energy of thirty foot drop with significant damage to cask body or seal region.
- Most damaging orientation.

Thermal Test

Total heat input defined by:

- Flame Temperature (1475°F)
- Time (30 minutes)
- Flame Emissivity (0.9)
- Cask Absorptivity (0.8)
- Location (fully engulfing)

Heat Absorbed by a Cask during the Thermal Test

From radiation (80 %) :

$$Q = \delta \, A F_{12} \, (T^4_{fire} - T^4_{cask}) \, \Delta \, time$$

$$where \; F_{12} = \frac{1}{(1/\varepsilon + 1/\alpha - 1)}$$

From convection (20 %) :

$$Q = h \, A \, (T_{fire} - T_{cask}) \, \Delta \, time$$

Effect of View factors

From NUREG/CR-4829, Vol.2, Appendix F

$$F_{12}\text{ (real fire)} = \frac{1}{(1/\ F12) + [(1/\varepsilon)-1] + (A_1/A_2)\ [(1/\alpha)\ - 1]}$$

$$F_{12}\text{ (thermal test)} = \frac{1}{(1/\varepsilon + 1/\alpha\ - 1)}$$

$$\frac{F_{12}\text{ (real fire)}}{F_{12}\text{ (thermal test)}} = 0.78$$

Thermal test at 1475°F generates the same heat load on a cask as a 1700°F fire.

Real Fires

- Fires occur in a very small percent of accidents.
- Most accidents involving fires do not reach the temperature and duration in Type B tests.
- A large quantity of fuel/combustibles is required for a 30 minute "fully engulfing" fire.
- Most fires would not be "fully engulfing" (e.g., fires change locations as they burn, casks would be shielded by other objects or the ground).
- Rail and Truck casks have large thermal inertia.

What about Tunnels ?

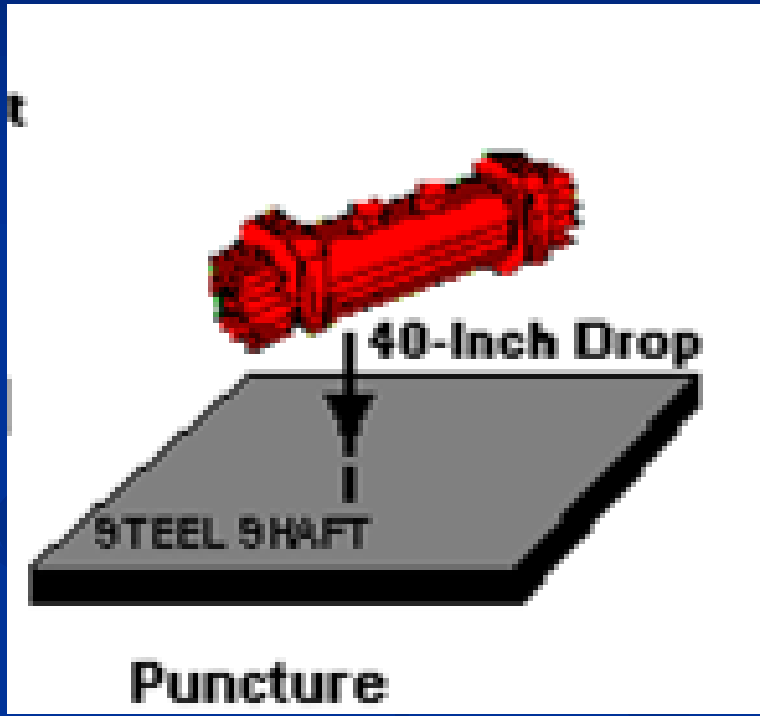
- Fires in road or rail tunnels can present a severe thermal environment.
- Long tunnels can provide a furnace-like environment.
- Depending on ventilation, fires in tunnels can be oxygen starved.
- Maximum temperatures will be limited for oxygen starved fires.

What about Tunnels ? (cont.)

- NRC conducted a study of the 2001 Baltimore tunnel fire effect on a rail transport cask.
- Normal (pre-fire) conditions for the cask per 10 CFR 71.71.
- Cask placed at a distance of 20 meters from fire source (per 49 CFR 174.85).
- No failure of cask for 7 hour fire.
- Fully engulfing fire (10 CFR 71.73) provides more severe boundary conditions.

Puncture Test

- Free drop of 40 inches onto a mild steel bar.
- Bar diameter = 6 inches.
- Puncture energy defined by package weight. (Potential energy = mgh).
- Energy focused on limited area = 29 in^2.



Real Puncture

- More of a problem for thin walled packages.
- Area of concern on thick walled casks are limited to closures, drain holes, vents, etc.
- Typical puncture energy for 100 ton rail cask is : mgh = 200000 lb. x 3.3 ft = 670,000 ft-lbs.

Immersion Test

- Based on estimate that water depths near most bridges, roadways or harbors would be less than fifty feet.

- Equal to external pressure of 21.7ft-lb per in^2.

- Not a problem for spent fuel casks.

Deep Immersion Test

- Spent fuel casks must withstand external pressure of 290 psi for one hour without buckling, collapse or inleakage of water.
- Equivalent to immersion in 200 meters of water.
- US requirements more stringent that IAEA.
- Meant to facilitate recovery, not included in hypothetical accident condition tests.

Final Thoughts

- Type B accident condition tests provide a high degree of protection against real life accidents.
- NRC periodically re-assesses the effectiveness of Type B standards to reflect changes in package design and accident statistics.