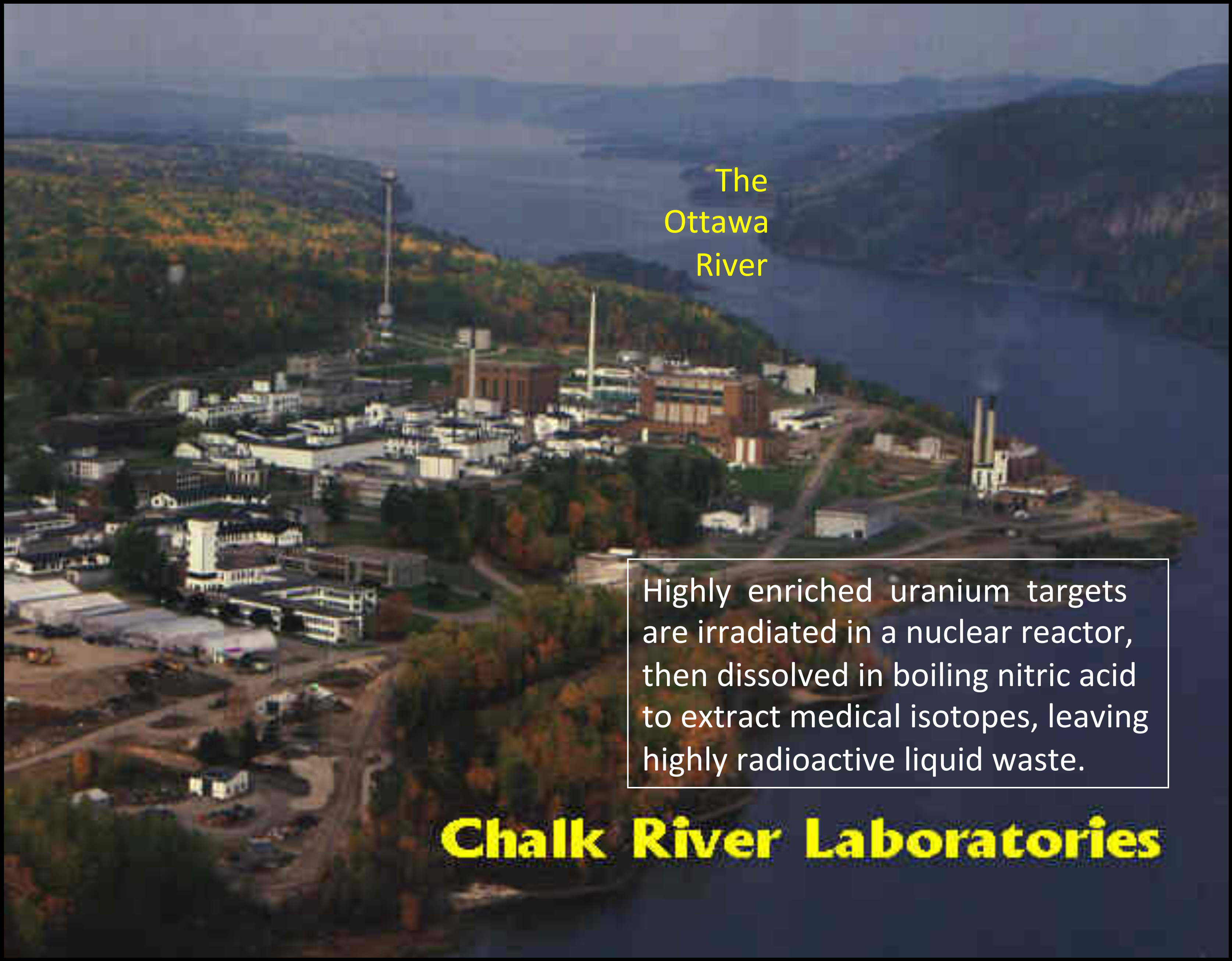
Radioactive Roads

Highly Radioactive Liquid Transport
from Chalk River, Ontario,
to SRS, South Carolina

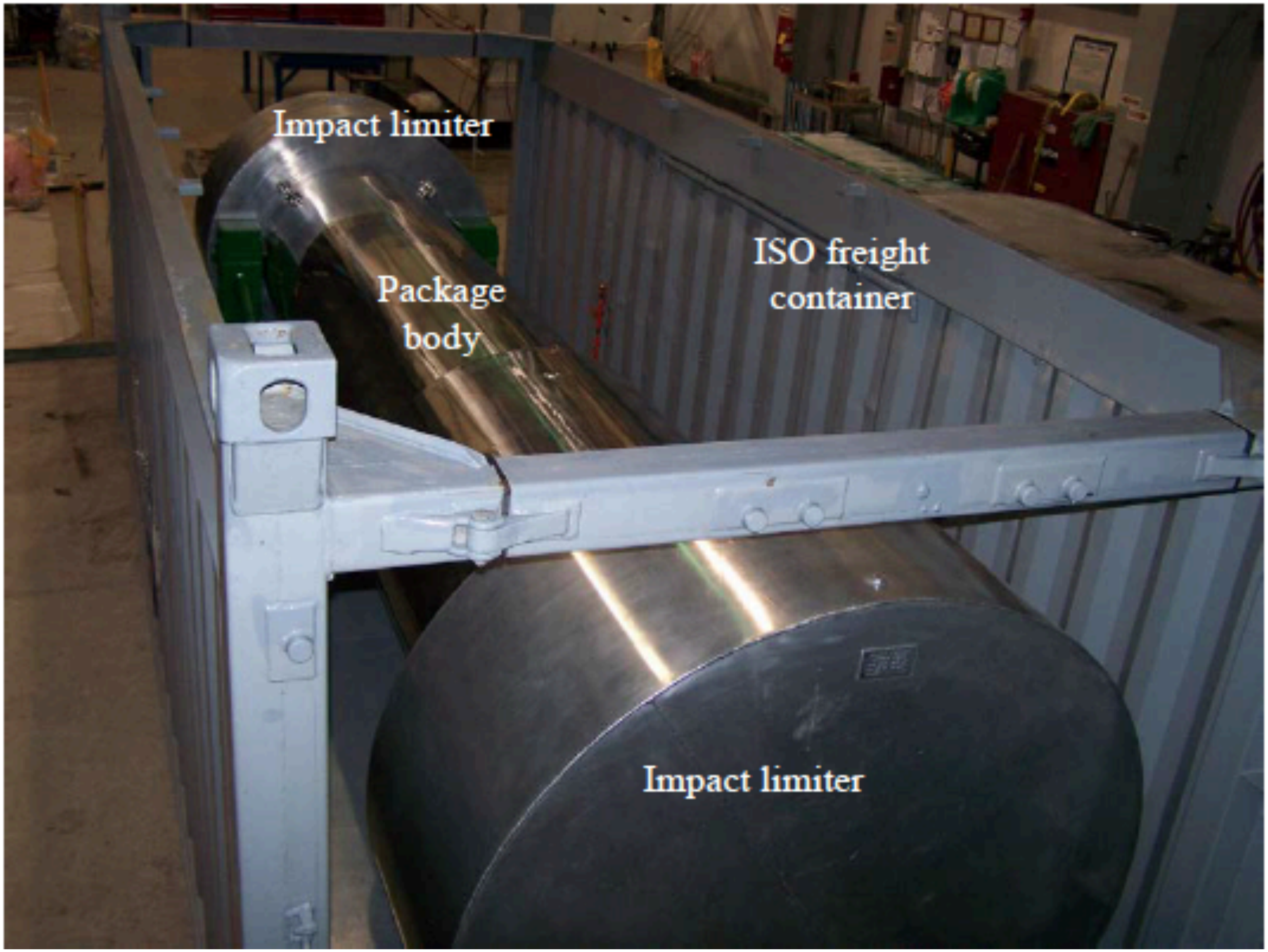

The Ottawa River
Highly enriched uranium targets are irradiated in a nuclear reactor, then dissolved in boiling nitric acid to extract medical isotopes, leaving highly radioactive liquid waste.
Chalk River Laboratories

23,000 litres of highly radioactive liquid waste are to be trucked from Chalk River to South Carolina

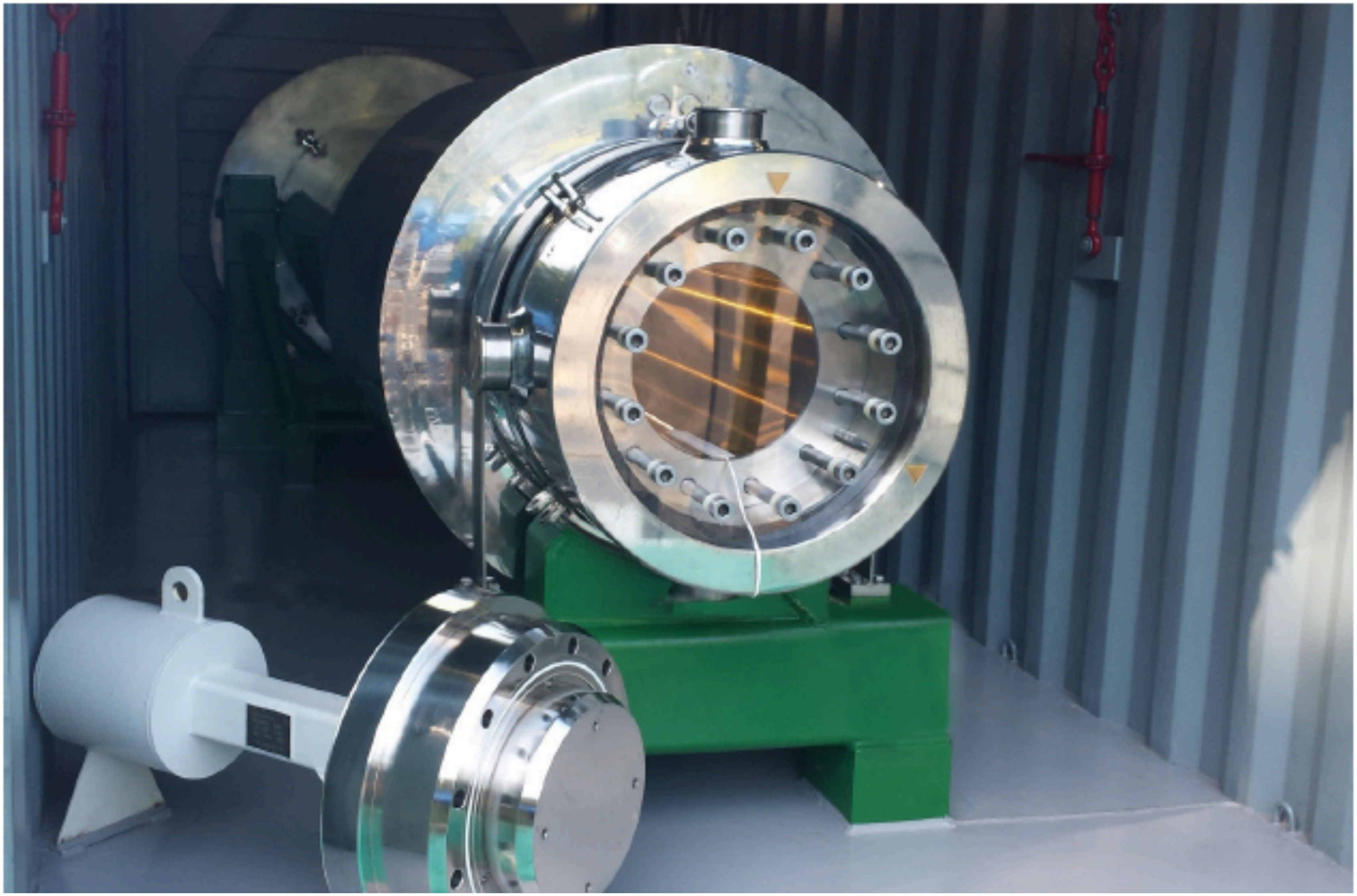
Stated rationale: *to eliminate stocks of weapons-grade uranium from Canadian soil*

Transport Truck with ISO Container in which the NAC-LWT Cask is Carried

The NAC-LWT cask was designed over 30 years ago to carry solid irradiated fuel elements.
It has never before been used to carry liquid highly radioactive waste.

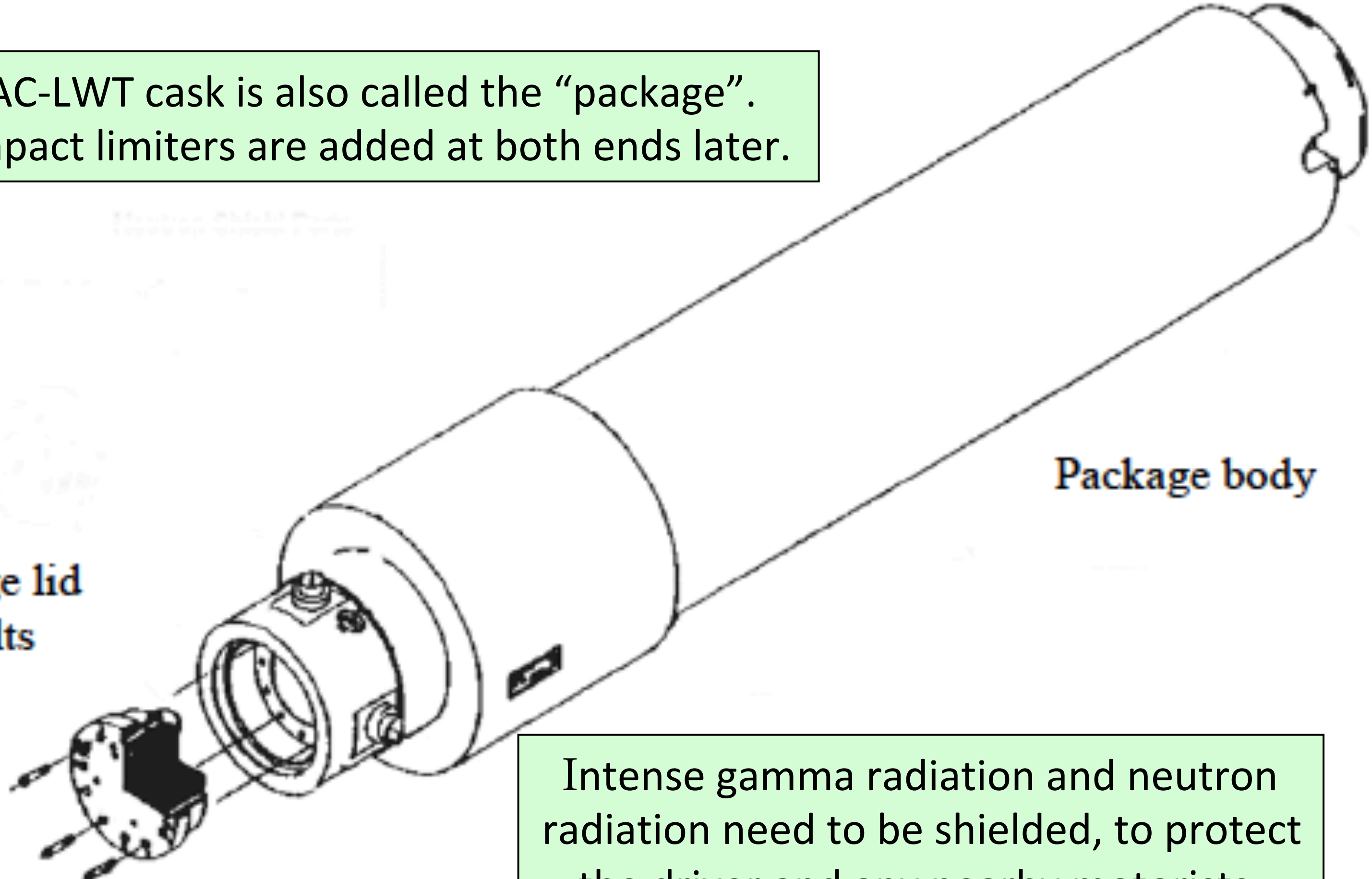


NAC-LWT cask with impact limiters, inside a truck's shipping container. The impact limiters are designed to absorb the shock of an impact.



The inner cavity holds the intensely radioactive cargo: it was designed to hold one or two fuel assemblies, or a few individual fuel pins.

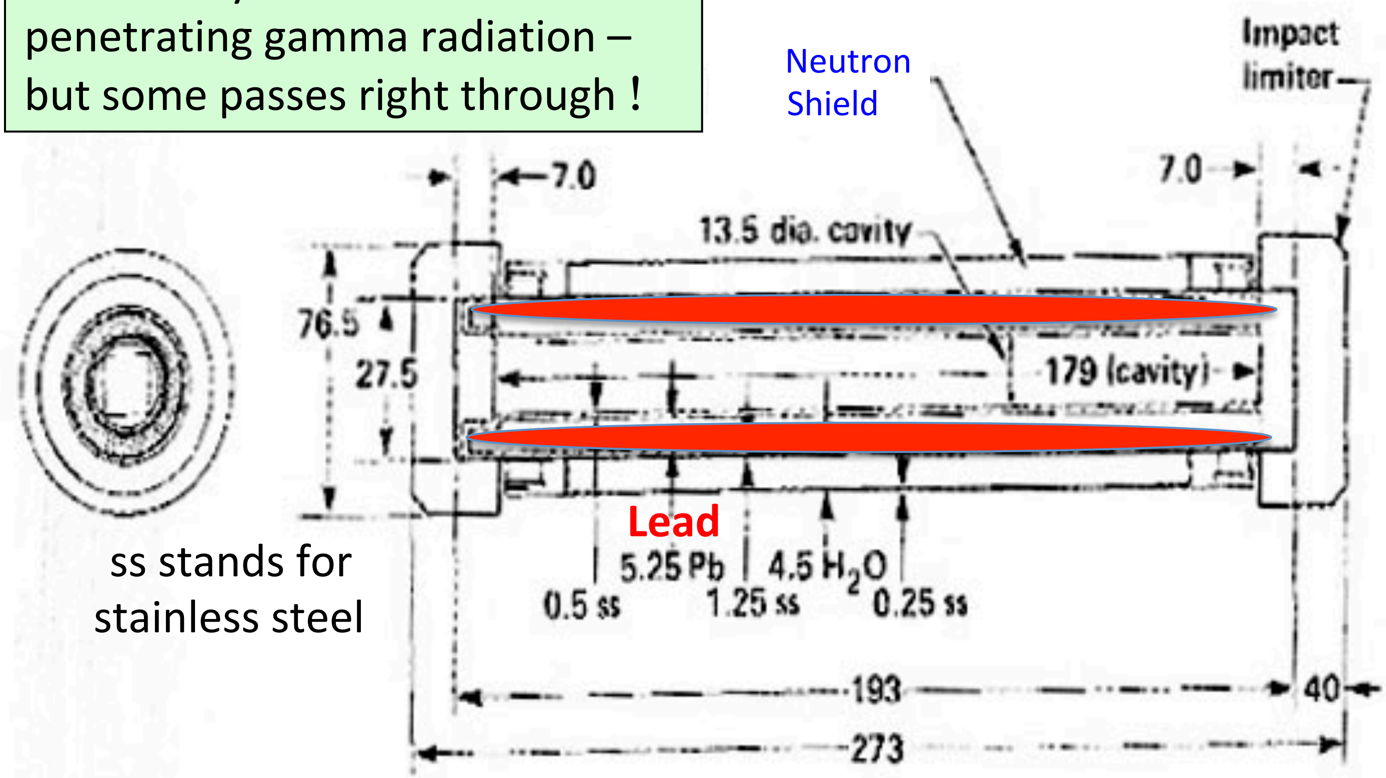
The NAC-LWT cask is also called the “package”.
The impact limiters are added at both ends later.



Intense gamma radiation and neutron radiation need to be shielded, to protect the driver and any nearby motorists.

Figure 1: NAC-LWT main package

A 5-inch layer of lead reduces the penetrating gamma radiation – but some passes right through !



ss stands for stainless steel

All dimensions are in inches.

There is also a neutron radiation shield blanketing the outer body of the package

Item	Weight (pounds)
Body	32,000
Limiter	4,500
Contents	2,500

The radioactive liquid is carried in 4 inner containers placed inside the inner cavity.

CNSC's data on the radioactive contents of the liquid.
(CNSC = Canadian Nuclear Safety Commission)

Table 2: Concentration of radionuclides in the solution (actinides, gamma emitters and their daughter products)

Isotope	Activity (Bq/L)	Isotope	Activity (Bq/L)	Isotope	Activity (Bq/L)
Nb-95	6.63E9	Ba-137m	70.19E9	Eu-155	1.95E8
Nb-95m	25.35E9	Cs-137	70.19E9	U-234	2.84E7
Zr-95	25.35E9	Ba-140	58.50E9	U-235	5.59E5
Rh-103m	18.13E9	La-140	58.50E9	U-236	3.66E5
Ru-103	18.13E9	Ce-141	42.88E9	U-238	5.59E3
Rh-106	5.46E8	Ce-144	8.19E9	Np-237	4.51E3
Ru-106	5.46E8	Pr-144	8.19E9	Pu-239	1.3E6
I-131	19.50E9	Pr-144m	8.19E9	Pu-240	8.99E4
Xe-131m	19.50E9	Nd-147	15.80E9		
Te-132	10.33E9	Eu-154	8.4E7		

only 28 radionuclides are listed

This table, incomplete as it is, shows that the radioactivity of the liquid is more than 17,000 times greater than the radioactivity of the uranium content alone.

DOE data (also incomplete) on the radioactive contents of the liquid.

Table 3 Content of a Fully Loaded NAC-LWT Shipping Cask

Isotopes	Becquerel	Curie
U-234	6.53×10^{9}	1.76×10^{-1}
U-235	1.29×10^{8}	3.47×10^{-3}
U-236	8.42×10^{7}	2.27×10^{-3}
U-237	2.06×10^{12}	5.56×10^{1}
U-238	1.29×10^{6}	3.47×10^{-5}
Np-237	1.04×10^{6}	2.80×10^{-5}
Pu-239	2.99×10^{8}	8.07×10^{-3}
Pu-240	2.07×10^{7}	5.58×10^{-4}
Sr-90	1.01×10^{13}	2.73×10^{2}
Y-90	1.01×10^{13}	2.73×10^{2}
Y-91	2.42×10^{6}	6.52×10^{-5}
Zr-95	1.08×10^{7}	2.92×10^{-4}
Nb-95	2.39×10^{7}	6.46×10^{-4}
Ru-106	2.55×10^{11}	6.89
Rh-106	2.55×10^{11}	6.89
Te-127m	1.97×10^{6}	5.33×10^{-5}
Te-127	1.91×10^{7}	5.15×10^{-4}
I-129	2.94×10^{6}	7.95×10^{-5}
Cs-137	1.46×10^{13}	3.93×10^{2}
Ce-144	1.70×10^{12}	4.60×10^{1}
Pm-147	7.25×10^{12}	1.96×10^{2}

DOE = U.S. Department of Energy

only 21 radionuclides are listed

There are 33 radionuclides in the two tables combined – but the combined list is still incomplete!

This calculation shows that a single litre of the Chalk River liquid is enough to ruin the drinking water supply of any city in North America by exceeding all standards.

Annual radiation dose for members of the general public drinking water from Georgetown Reservoir, if one litre of liquid target residue material were added to 530 million litres of water in that reservoir.

name of radionuclide	EPA LIMITS Bq/l	Contents of the liquid: CNSC 2014 Bq/l	Contents of the liquid: DOE 2013 Bq/l	Annual radiation dose from contaminated water: mrem/y based on CNSC '14	mrem/y based on DOE '13	blended estimate of dose
strontium-90	0.296		4.35E+10		1.11E+03	1.11E+03
yttrium-90	2.22		4.35E+10		1.48E+02	1.48E+02
yttrium-91	3.33		1.04E+04		2.36E-05	2.36E-05
zirconium-95	7.4	2.54E+10	4.66E+04	2.59E+01	4.75E-05	2.59E+01
niobium-95	11.1	6.63E+09	1.03E+05	4.51E+00	7.00E-05	4.51E+00
niobium-95m	---	2.55E+10				0.00E+00
ruthenium-103	7.4	1.81E+10		1.85E+01		1.85E+01
rhodium-103m	1,110	1.81E+10		1.23E-01		1.23E-01
ruthenium-106	1.11	5.46E+08	1.10E+09	3.71E+00	7.48E+00	7.48E+00
rhodium-106	---	5.46E+08	1.10E+09			
tellurium-127	33.3		8.23E+04		1.87E-05	1.87E-05
tellurium-127m	7.4		8.49E+03		8.66E-06	8.66E-06
iodine-129	0.037		1.27E+04		2.59E-03	2.59E-03
iodine-131	0.111	1.95E+10		1.33E+03		1.33E+03
xenon-131m	--	1.95E+10				
tellurium-132	3.33	1.03E+10		2.34E+01		2.34E+01
cesium-137	7.4	7.02E+10	6.29E+10	7.16E+01	6.42E+01	7.16E+01
barium-137m	--	7.02E+10				
barium-140	3.33	5.85E+10		1.33E+02		1.33E+02
lanthanum-140	2.22	5.85E+10		1.99E+02		1.99E+02
cerium-141	11.1	4.29E+10		2.92E+01		2.92E+01
cerium-144	1.11	8.19E+09	7.33E+09	5.57E+01	4.98E+01	5.57E+01
praseodymium-144	--	8.19E+09				
praseodymium-144m	--	8.19E+09				
neodymium-147	7.4	1.58E+10		1.61E+01		1.61E+01
promethium-147	22.2		3.13E+10		1.06E+01	1.06E+01
europium-154	2.22	8.40E+07		2.86E-01		2.86E-01
europium-155	22.2	1.95E+08		6.63E-02		6.63E-02
				1.91E+03	1.39E+03	3.18E+03
		Calculated annual doses:		1,910 mrem	1,390 mrem	3,180 mrem

These calculated radiation exposures are several hundreds of times over the limit. They are based on one litre of radioactive liquid in the water supply of Washington DC.

Liquid contents can escape following a severe impact, a puncture, or prolonged fire.

The cask is designed to withstand certain conditions but is not actually tested.

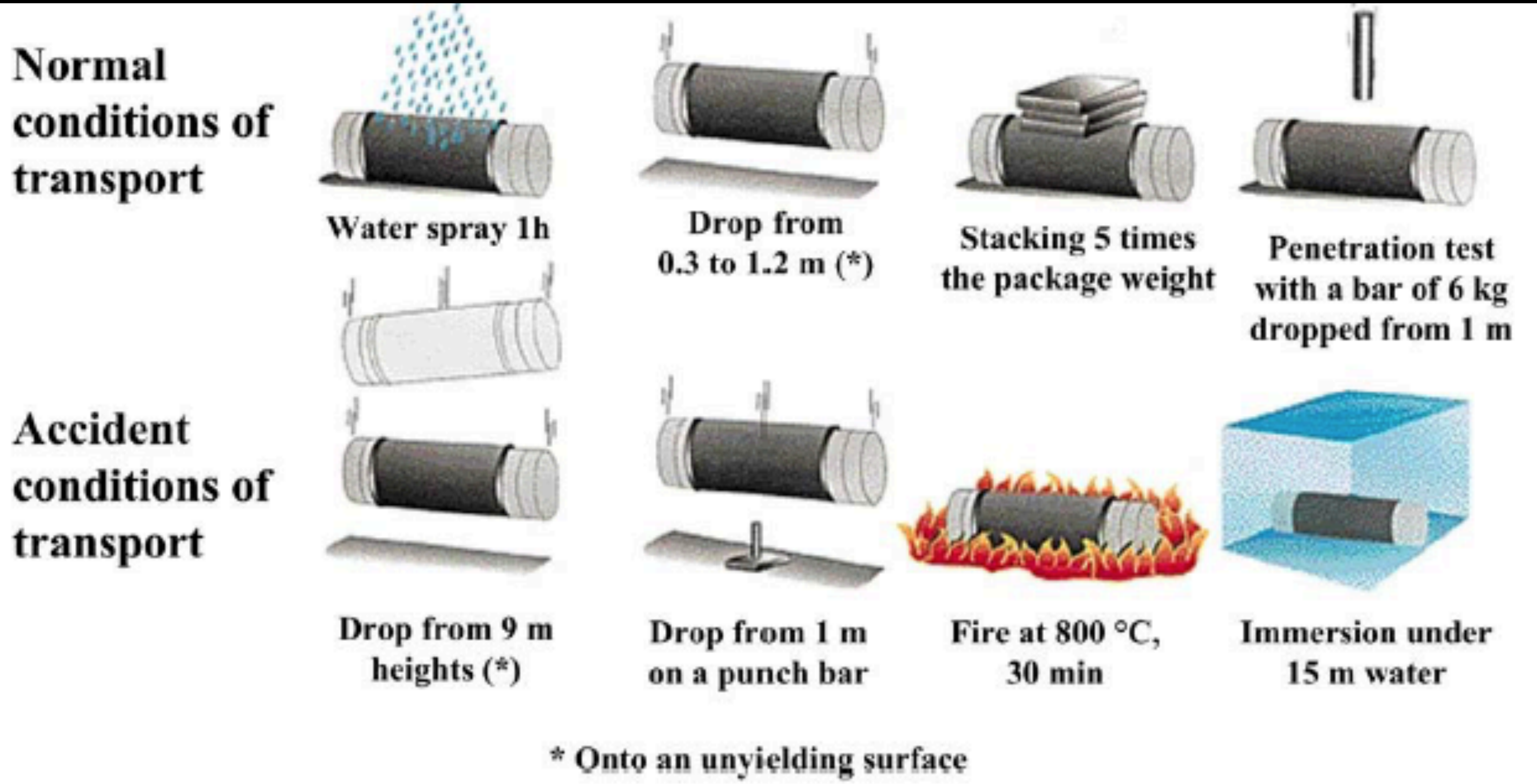


Figure 3: Type B regulatory requirements for normal and accident conditions of transport

In any event, independent analysis has shown that a sidewise impact can breach the cask and a realistically hot diesel fire (over 1000 degrees C) can also release the liquid contents.

These results are briefly documented in a paper by Dr. Marvin Resnikoff & Dr. Gordon Edwards.

Highly Radioactive Liquid Waste in NAC-LWT Cask

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Marvin Resnikoff
Radioactive Waste
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February 1, 2017

See www.ccnr.org/MR-GE_2017_rev2.pdf

This table comes from a report on cask failures written many years ago, shortly after the NAC Corporation first designed its NAC-LWT cask.

It shows that a side impact at a speed of only 12.5 miles per hour could establish an opening to the inner cavity of the cask.

TABLE 6.1 Summary of Spent Fuel Cask Mechanical Failure Threshold Estimates[a]

	Target	Cask Velocity km/hr (mph)	Failure Type
End Impact	Rigid Plane	78.1 (48.5)	Seal to Cask Cavity
	Rigid Plane	153 (95.5)	Larger Opening to Cask Cavity
	Rigid Plane	61.0 (37.9)	Rupture Disk Venting
Side Impact	Rigid Plane	64.7 (40.2)	Seal to Cask Cavity
	Rigid 1.5 m Column	20.1 (12.5)	Opening to Cask Cavity

(a) Taken from Appendix F

The impact limiters on either end of the package do not protect against a sidewise impact.

According to regulations, the fire is only allowed to burn for 30 minutes – and only at a temperature of 800 degrees C (that is, 1472 degrees F).

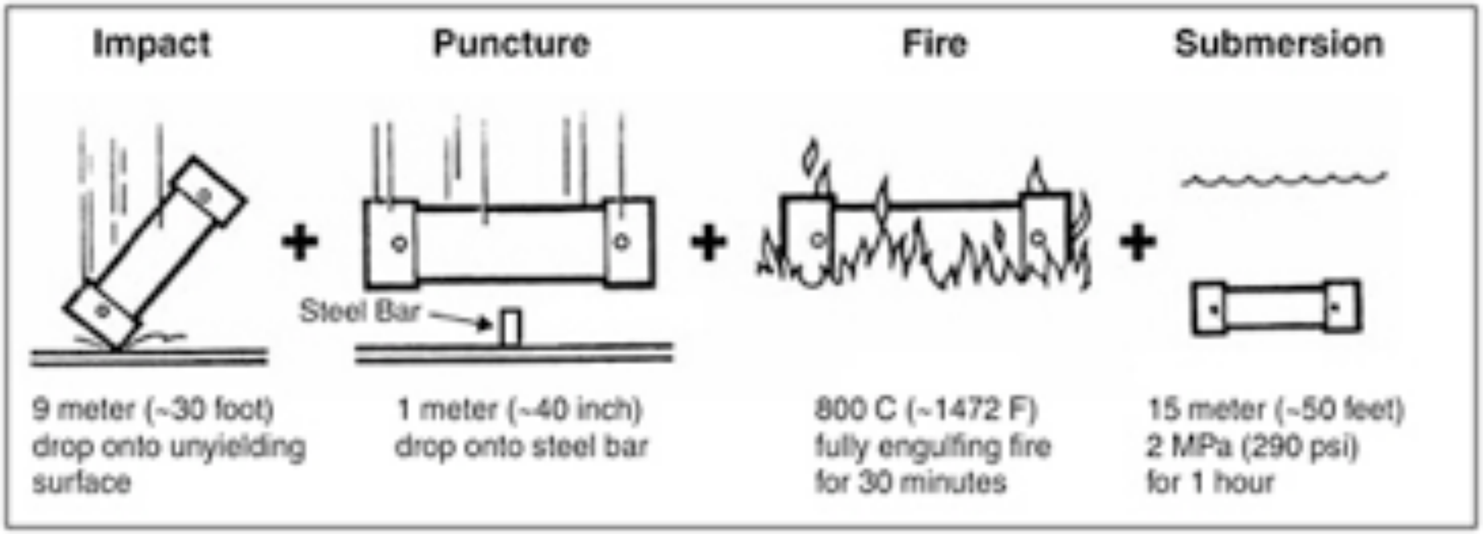
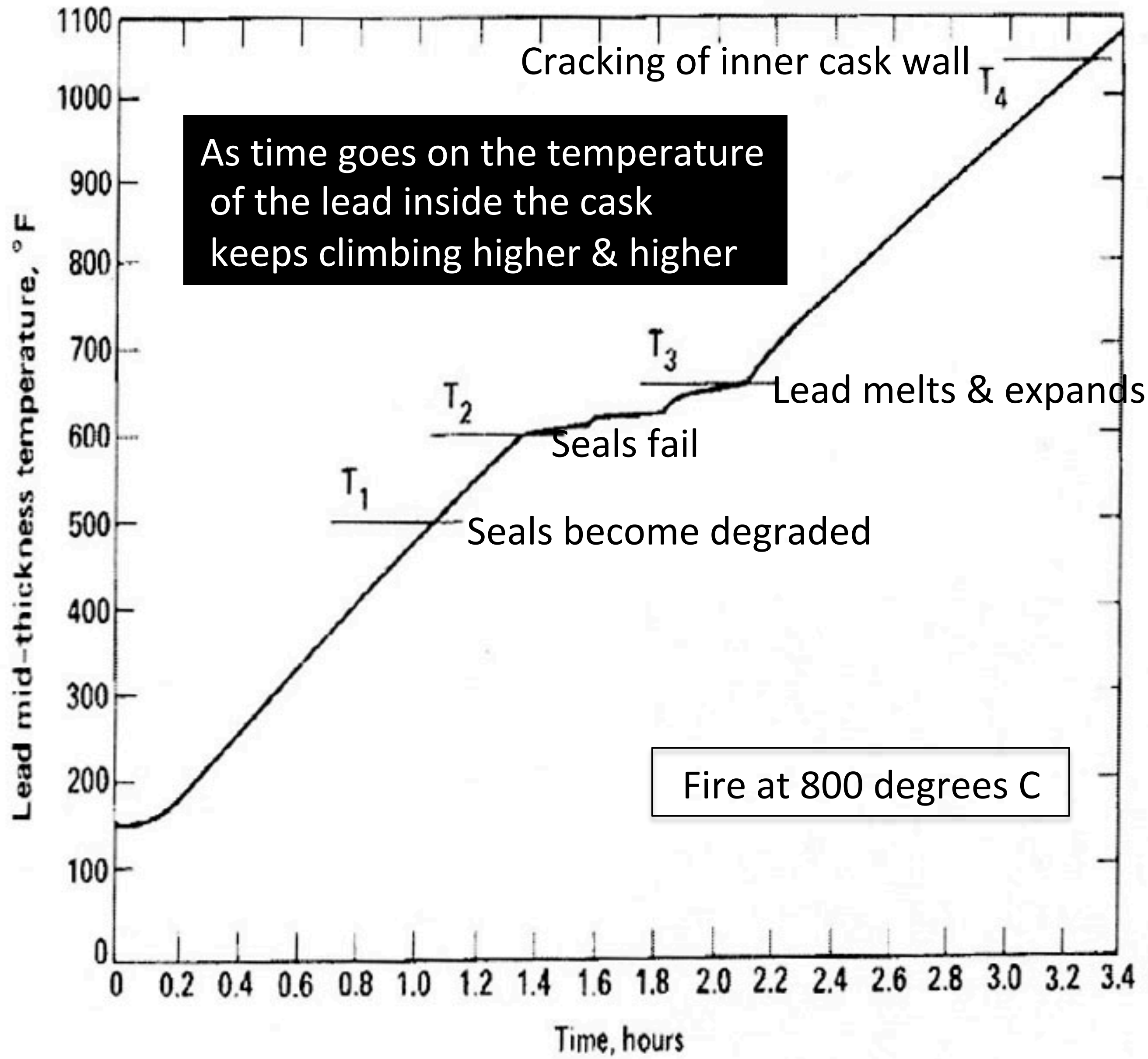
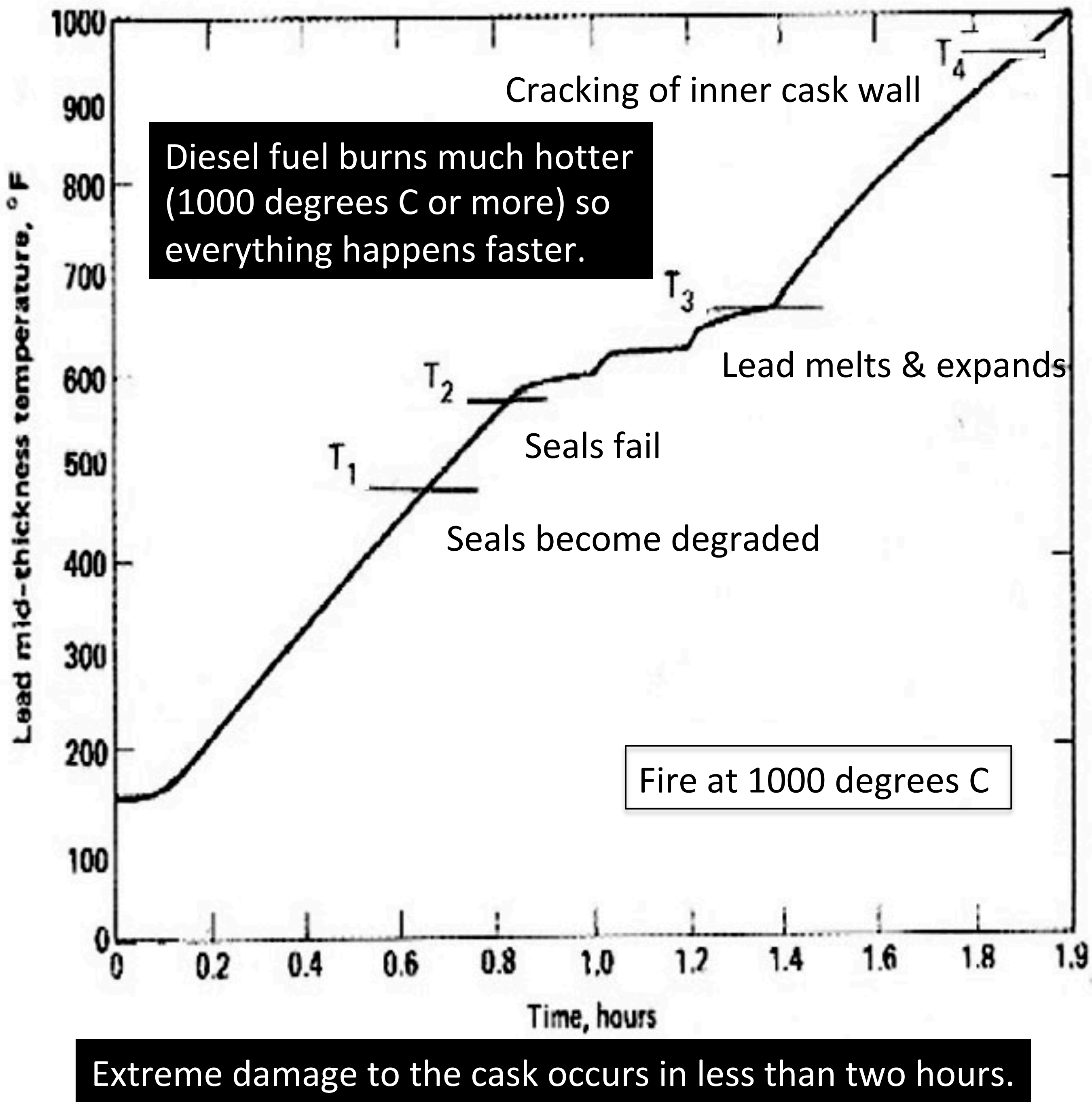


Fig. 1 Nuclear Regulatory Commission Hypothetical Accident Conditions

If an 800 degree fire lasts for two or three hours the results are alarming.



When lead melts it expands and cracks the inner cask wall.


Lead mid-thickness temperature, °F
1000
900
800
700
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
1.9
Time, hours
Diesel fuel burns much hotter (1000 degrees C or more) so everything happens faster.
Cracking of inner cask wall
T4
T3
Lead melts & expands
T2
Seals fail
T1
Seals become degraded
Fire at 1000 degrees C
Extreme damage to the cask occurs in less than two hours.

Even decades ago it was known that a 1010 degree fire can cause some serious damage to the cask in just 15 minutes to half an hour.

TABLE 5.3. Thermal Failure Thresholds

Type of Failure	Minimum Duration of Fire[a] to Cause Failure
Loss of Coolant from Rupture Disk	15 min.
Closure Seal	30 min.
Drain Valve Seal	30 min.
Vent Valve Seal	30 min.

(a) All fires assumed to be 1010°C (1850°F).

When can we expect the
100-150 shipments to take place?

Beginning this Spring

Possibly this month
(March 2017)

How many shipments will there be, and over what period of time?

100-150 truckloads

Over a period of 4 years

The End

For more information:
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