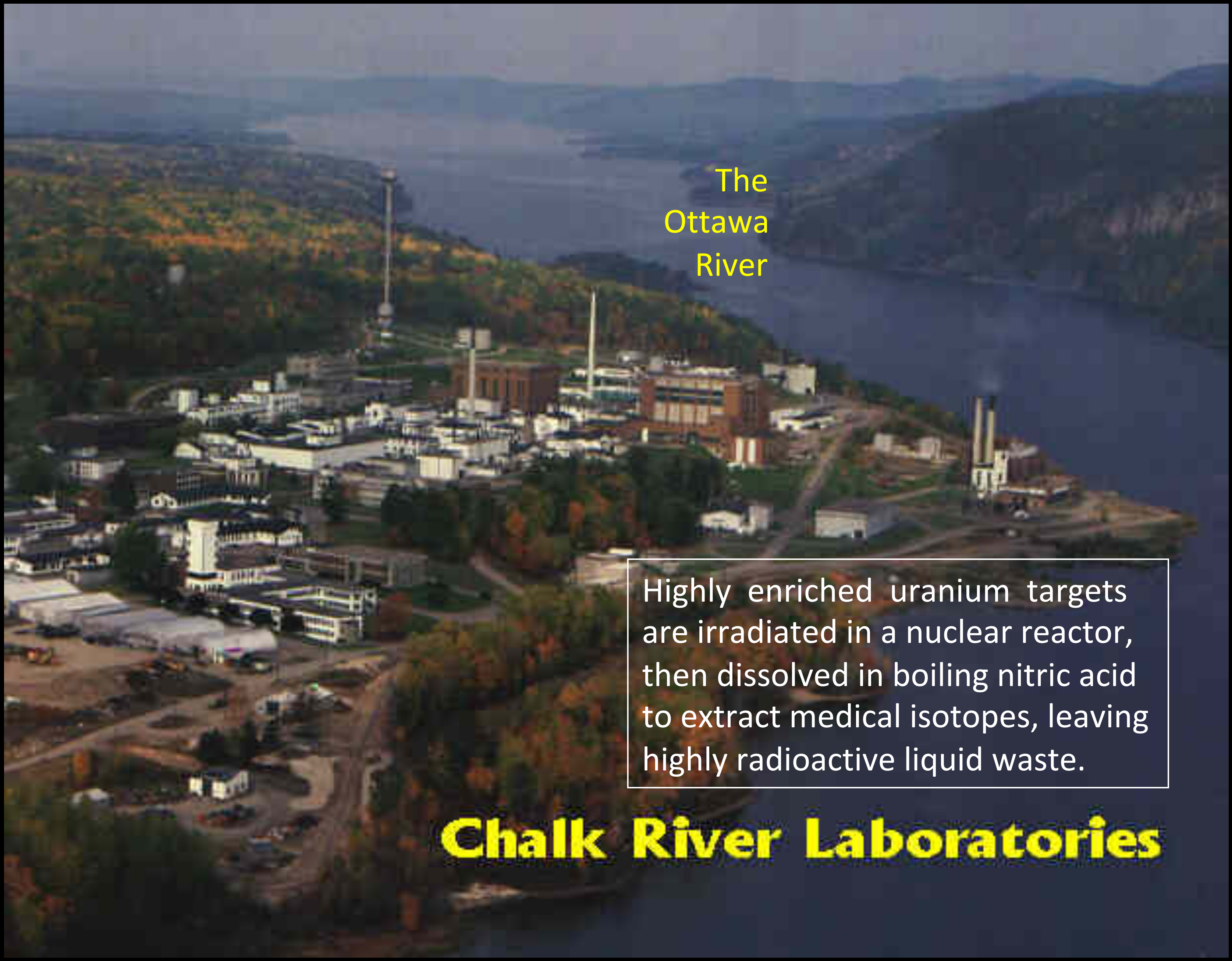
Radioactive Roads

Transporting Highly Radioactive Liquid Over Public Roads and Bridges In the Niagara Region

a presentation by Gordon Edwards Ph.D.
Beamsville Ontario June 16 2017
ccnr @ web.ca

Part 1 : The Plan

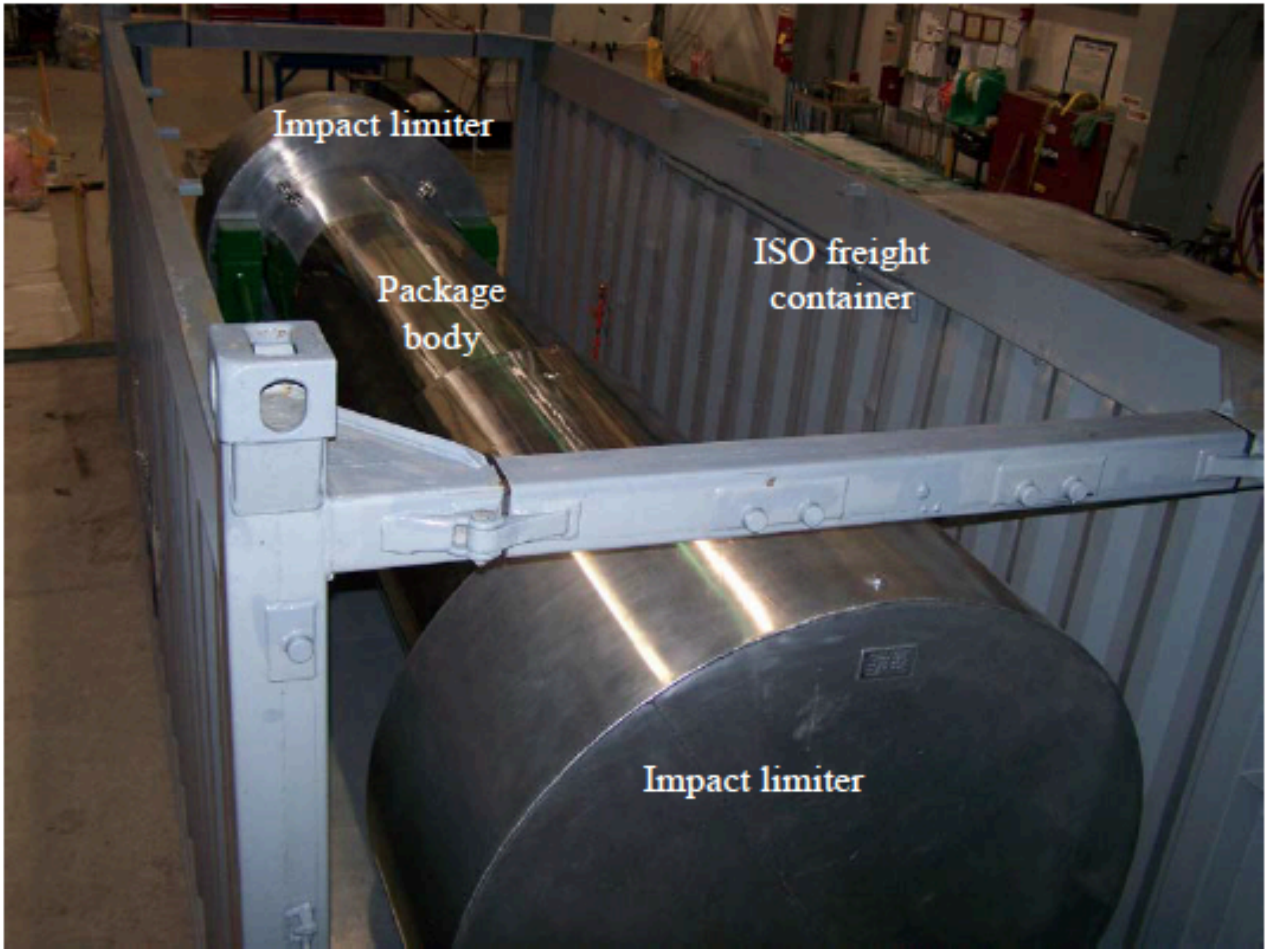

The Ottawa River
Highly enriched uranium targets are irradiated in a nuclear reactor, then dissolved in boiling nitric acid to extract medical isotopes, leaving highly radioactive liquid waste.
Chalk River Laboratories

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

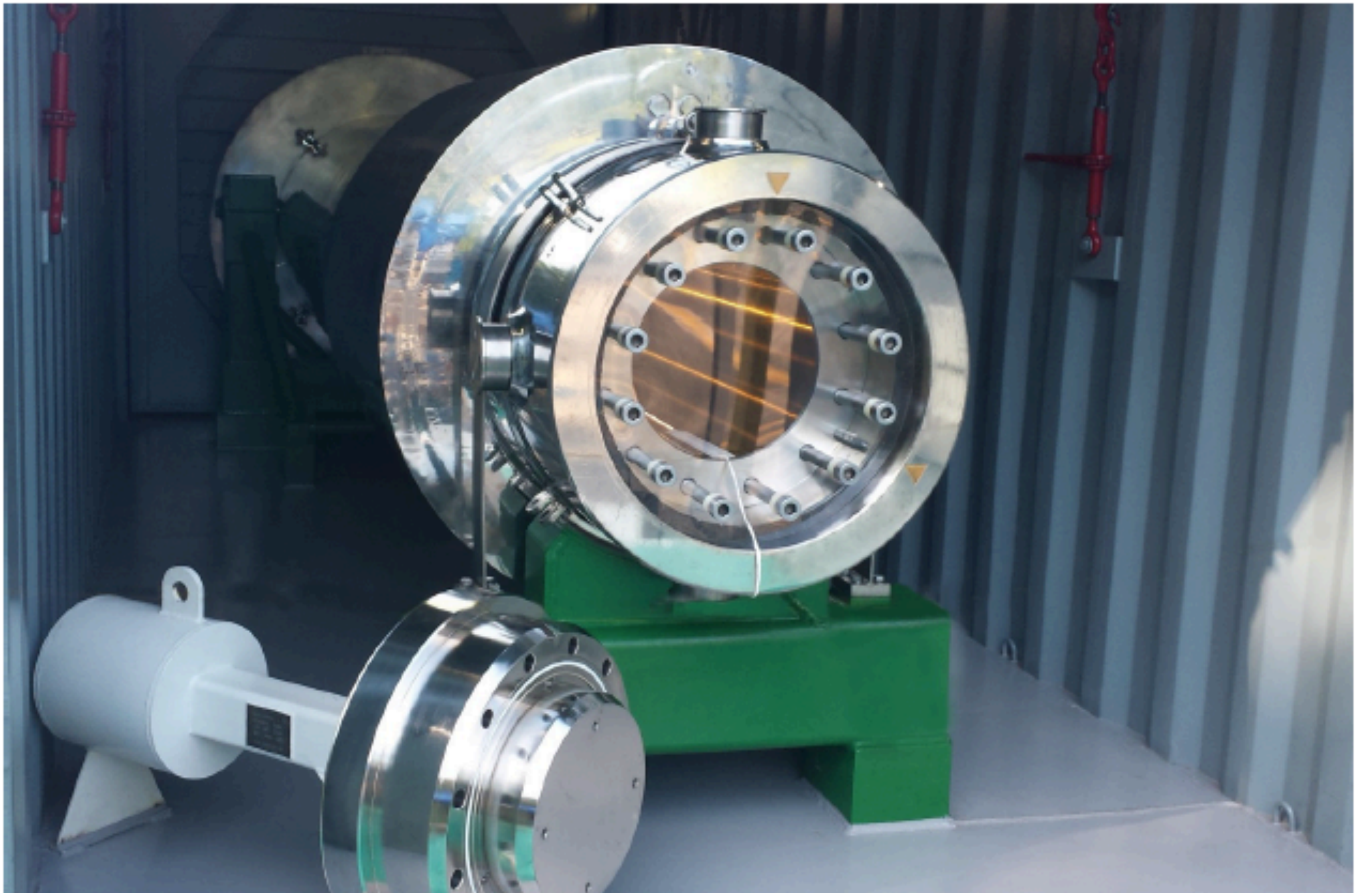
Stated rationale: *to eliminate stocks of weapons-grade uranium from Canadian soil*

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 highly radioactive liquid.

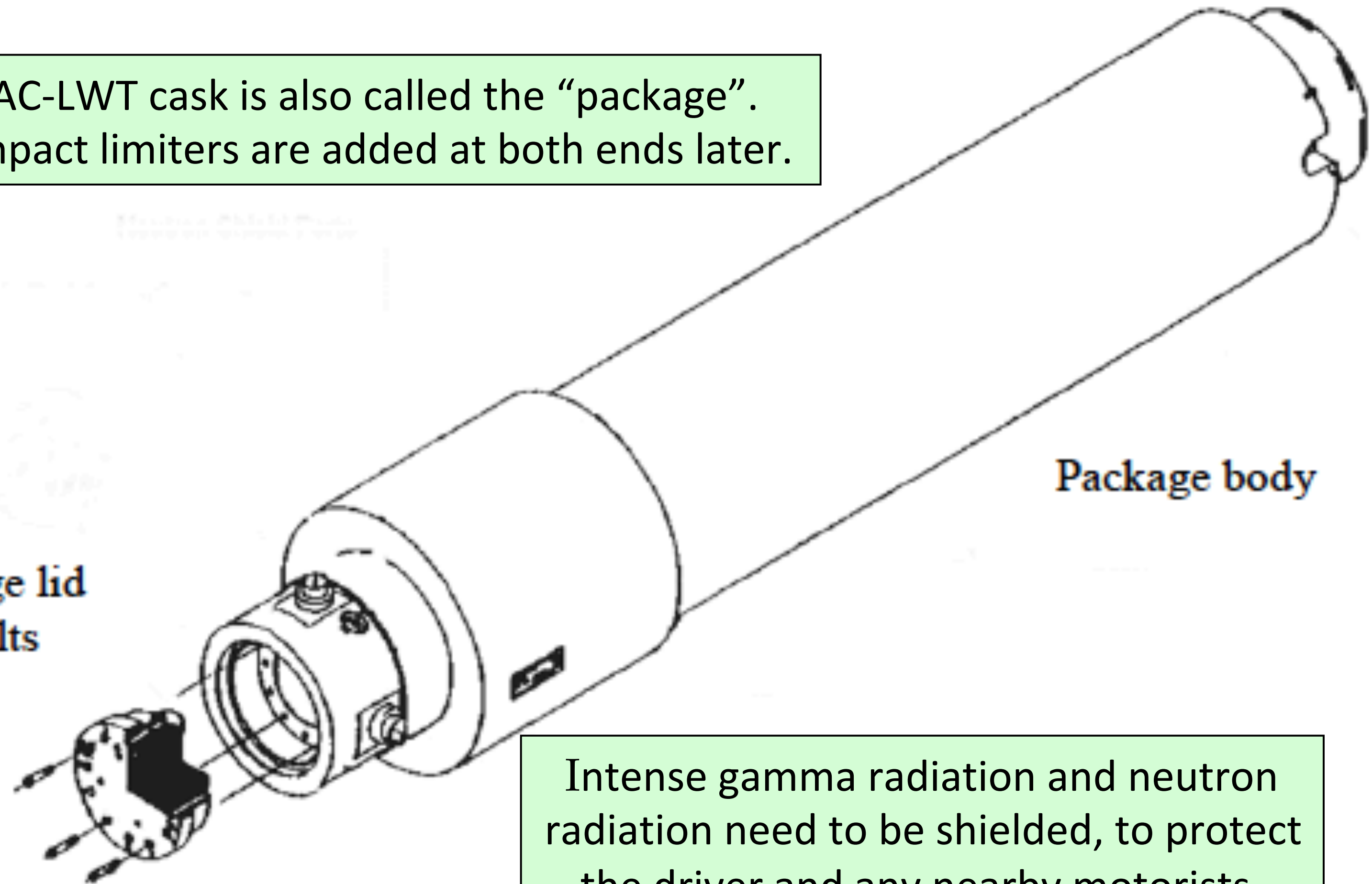


NAC-LWT cask with impact limiters, inside a truck's shipping container. The impact limiters are designed to absorb the shock of an impact.



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

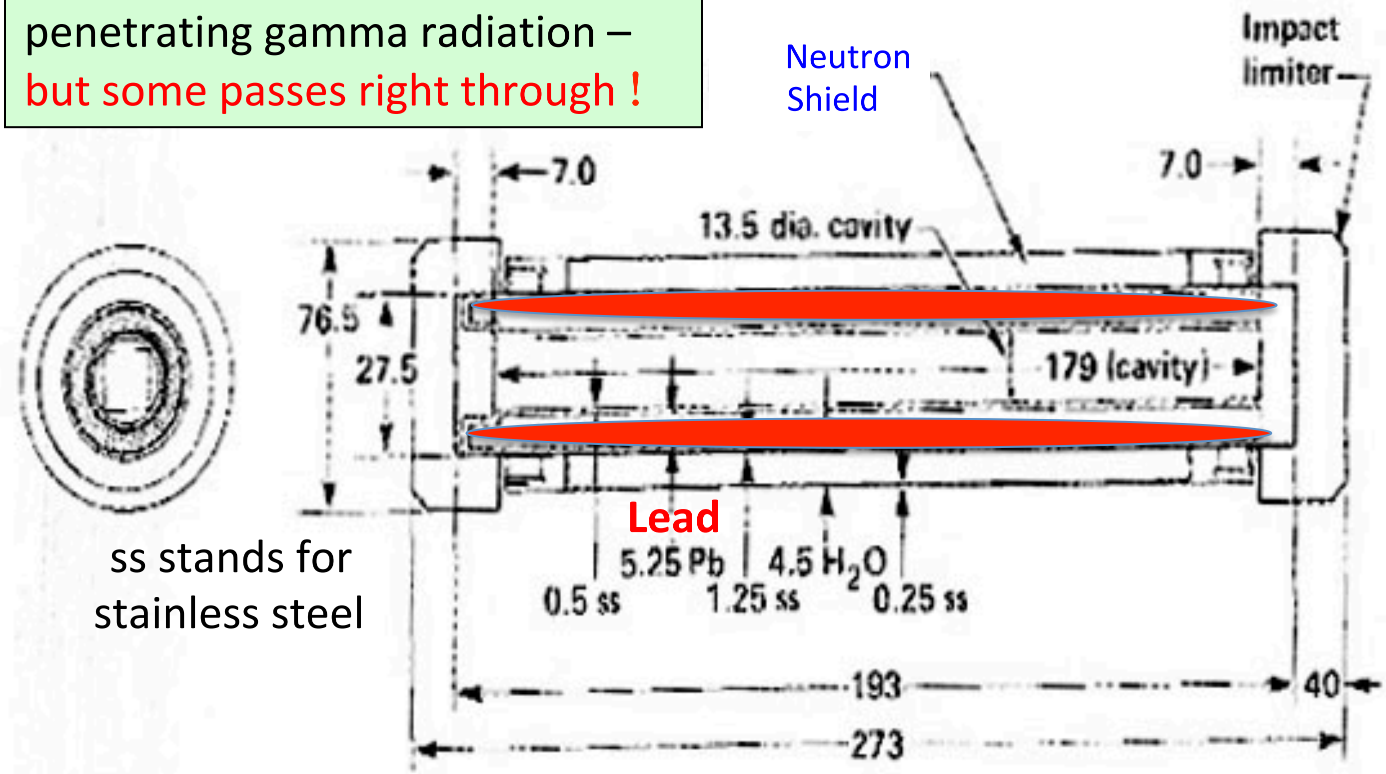
The NAC-LWT cask is also called the "package".
The impact limiters are added at both ends later.



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 !



All dimensions are in inches.

There is also a neutron radiation shield blanketing the outer body of the package. But some of the neutron radiation still gets through !

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.

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.

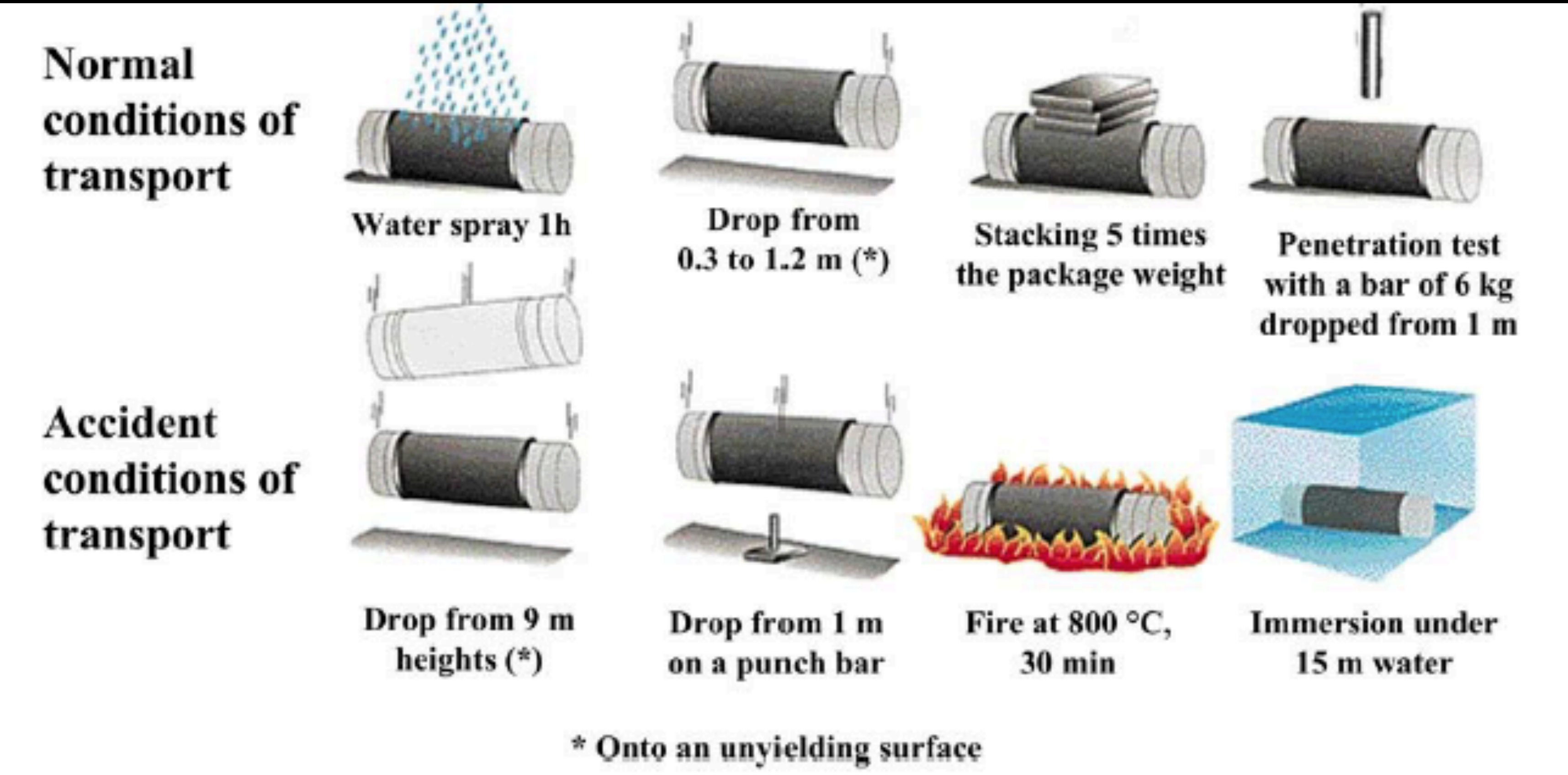


Figure 3: Type B regulatory requirements for normal and accident conditions of transport

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

Gordon Edwards
Canadian Coalition
for Nuclear Responsibility[1]

Marvin Resnikoff
Radioactive Waste
Management Associates[2]

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 assumed to burn for 30 minutes – and only at a temperature of 800 degrees C (that is, 1472 degrees F).

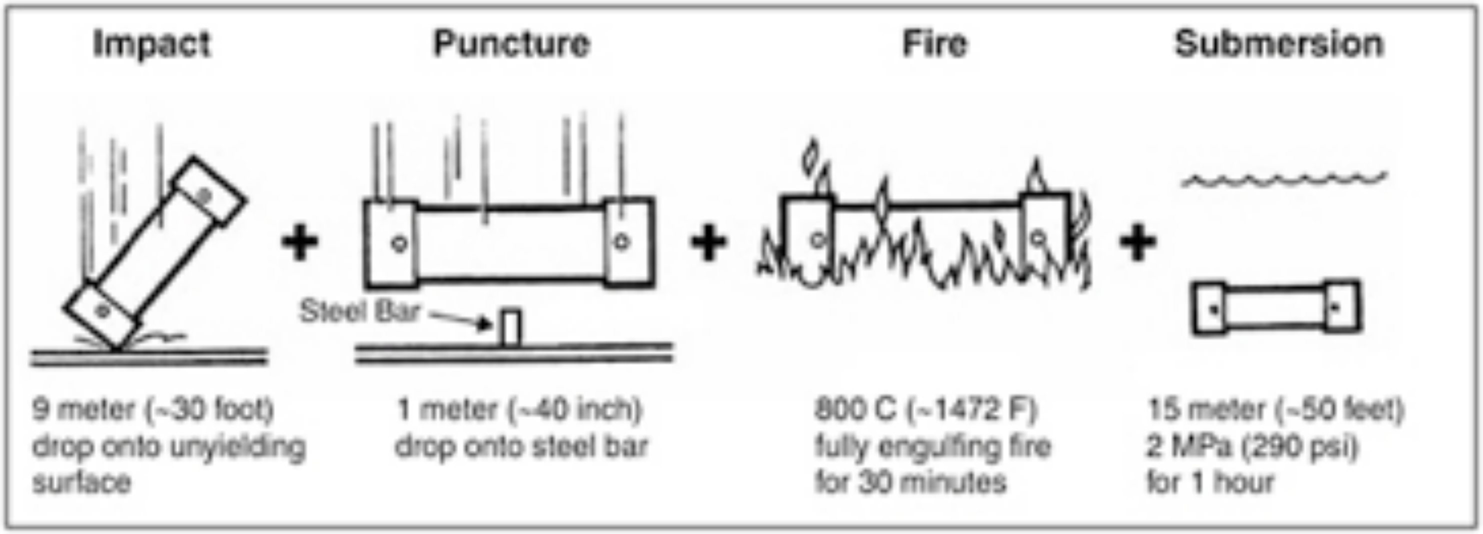
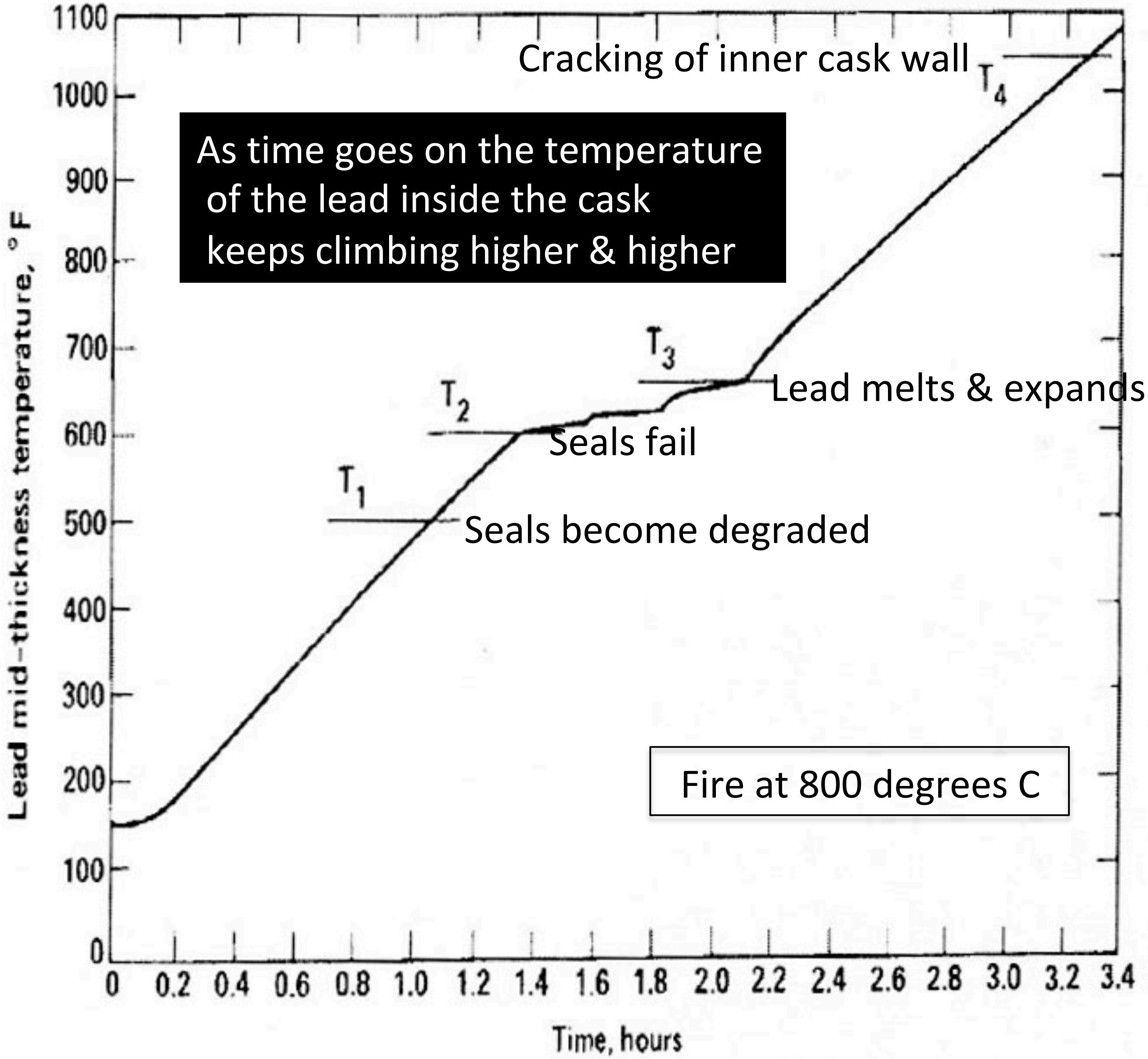


Fig. 1 Nuclear Regulatory Commission Hypothetical Accident Conditions

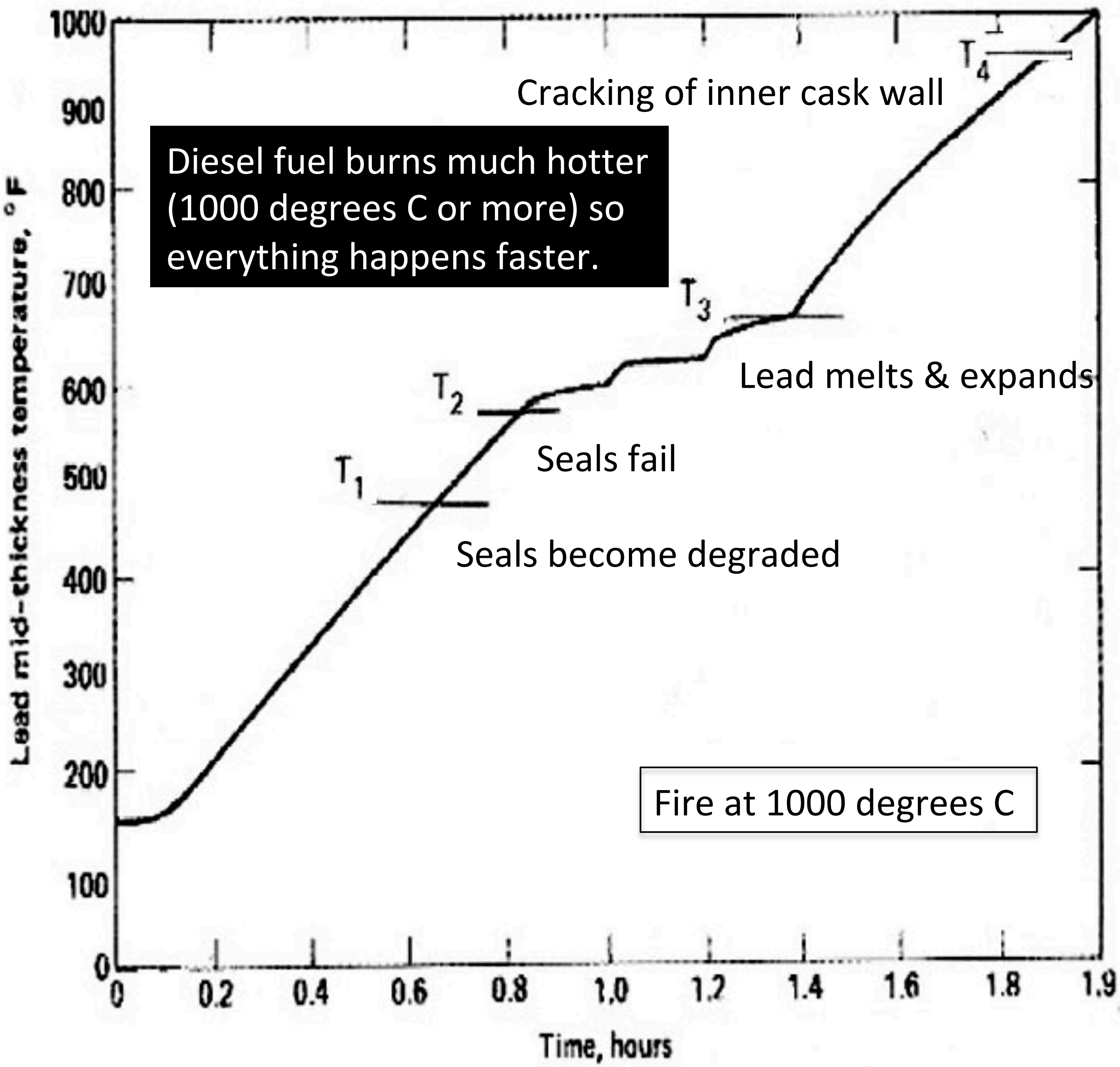
If an 800 degree fire lasts for two or three hours the results are alarming.



Almost 3 ½ hours

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

Less than
2 hours



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).

U.S. DEPARTMENT OF ENERGY | OFFICE OF ENVIRONMENTAL MANAGEMENT

A recent slide show from the Savannah River Site, where the Chalk River liquid is to be processed in the "H Canyon".

Presentation on Target Residue Material

The US authorities describe the Chalk River liquid as "Target Residue Material".

Tony Polk
Jay Ray
Nuclear Materials Programs Division
Department of Energy-Savannah River
Savannah River Site Citizen Advisory Board
May 23, 2017

Purpose

- To Provide an overview of the Target Residue Material Handling in H-Canyon

Overview

- Intermodal Container (aka ISO* Container) with a Legal Weight Transport (LWT) Cask inside, being transported to H-Canyon

The first shipment of Chalk River liquid arrives at SRS in South Carolina in April 2017.

* ISO = International Organization for Standardization

OFFICE OF ENVIRONMENTAL MANAGEMENT

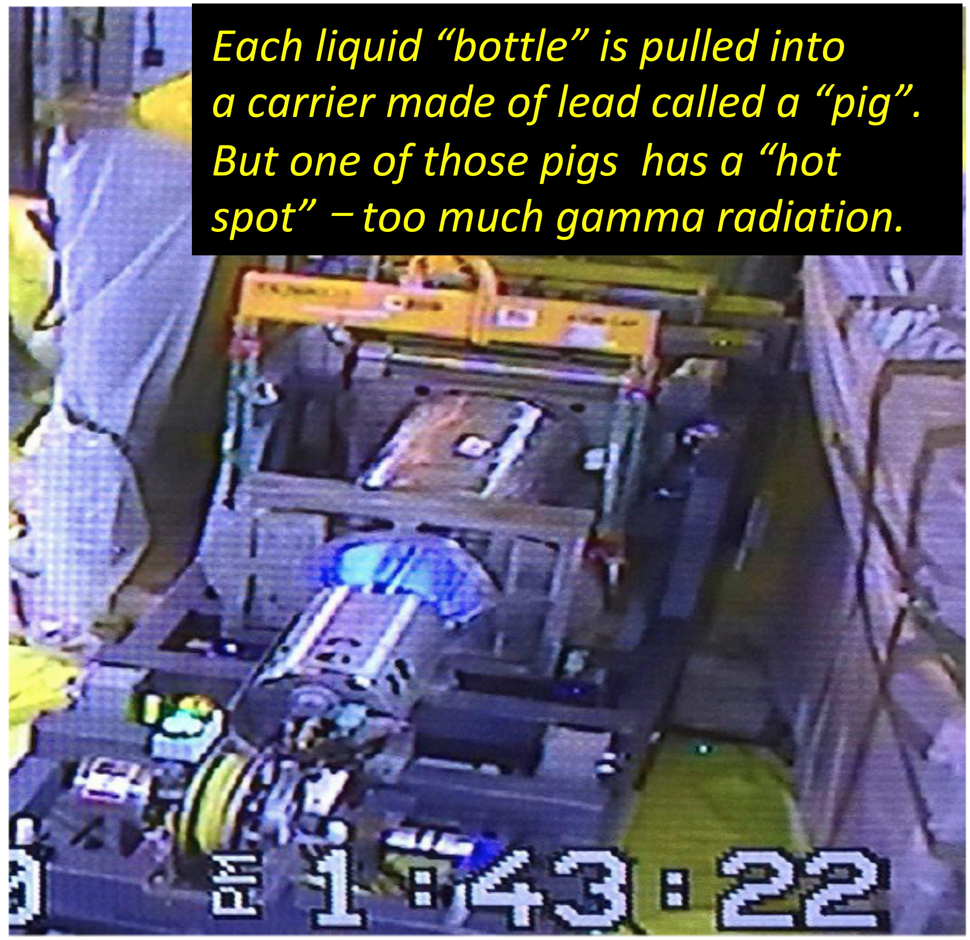
Overview

- Container has been wrapped to prevent contamination of the ISO container and cask
- Load mover* (tug) is moving the ISO container into the truck well

* Load Movers (tugs) are also used to move airplanes at airports

Overview

- The cask impact limiter and cask plug have been removed
- The cask is in the upper part of the picture with the end of the cask barely visible.
- The Container Retrieval System has been mounted to the cask and is preparing to pull a container into the pig (shown in horizontal position near the middle of the picture).
- The gripper used to remove the container from the cask is in the lower left corner of the picture

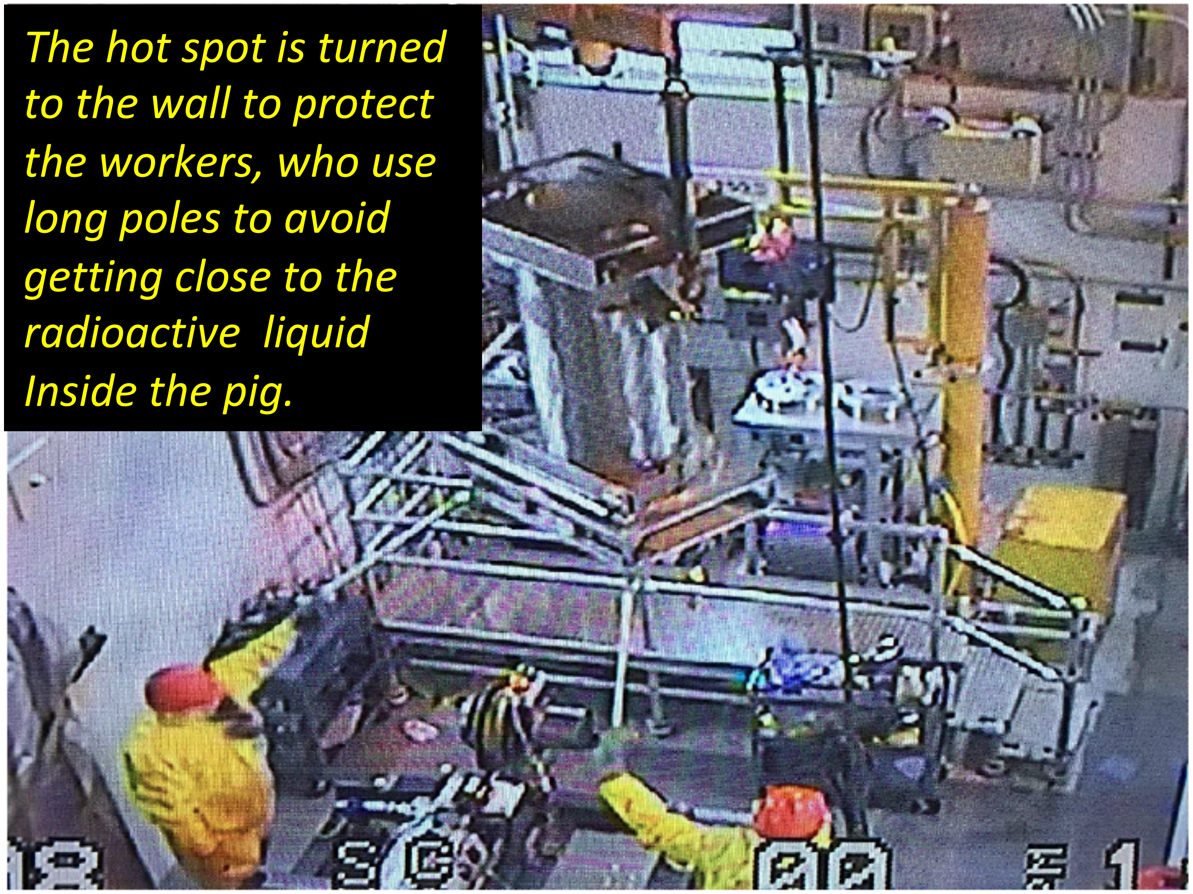


Each liquid "bottle" is pulled into a carrier made of lead called a "pig". But one of those pigs has a "hot spot" – too much gamma radiation.

Overview

- Pig is being moved to the Container Unloading Station
- Note the use of remote reach tools again

The hot spot is turned to the wall to protect the workers, who use long poles to avoid getting close to the radioactive liquid Inside the pig.



In case of an accident en route, first responders have none of this experience or training.

Even without leakage, damage to the shielding inside the cask can lead to unexpectedly high doses.

When can we expect the shipments to take place?

Beginning this Spring

First Shipment
mid-April 2017

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

100-150 truckloads
over a period of 4 years
(original plan)

Part 2 : Risk of Criticality

What is Nuclear Energy?

Every atom has a tiny core called the NUCLEUS.
It is surrounded by one or more orbiting electrons.

Chemical energy involves only the outer electrons . . .

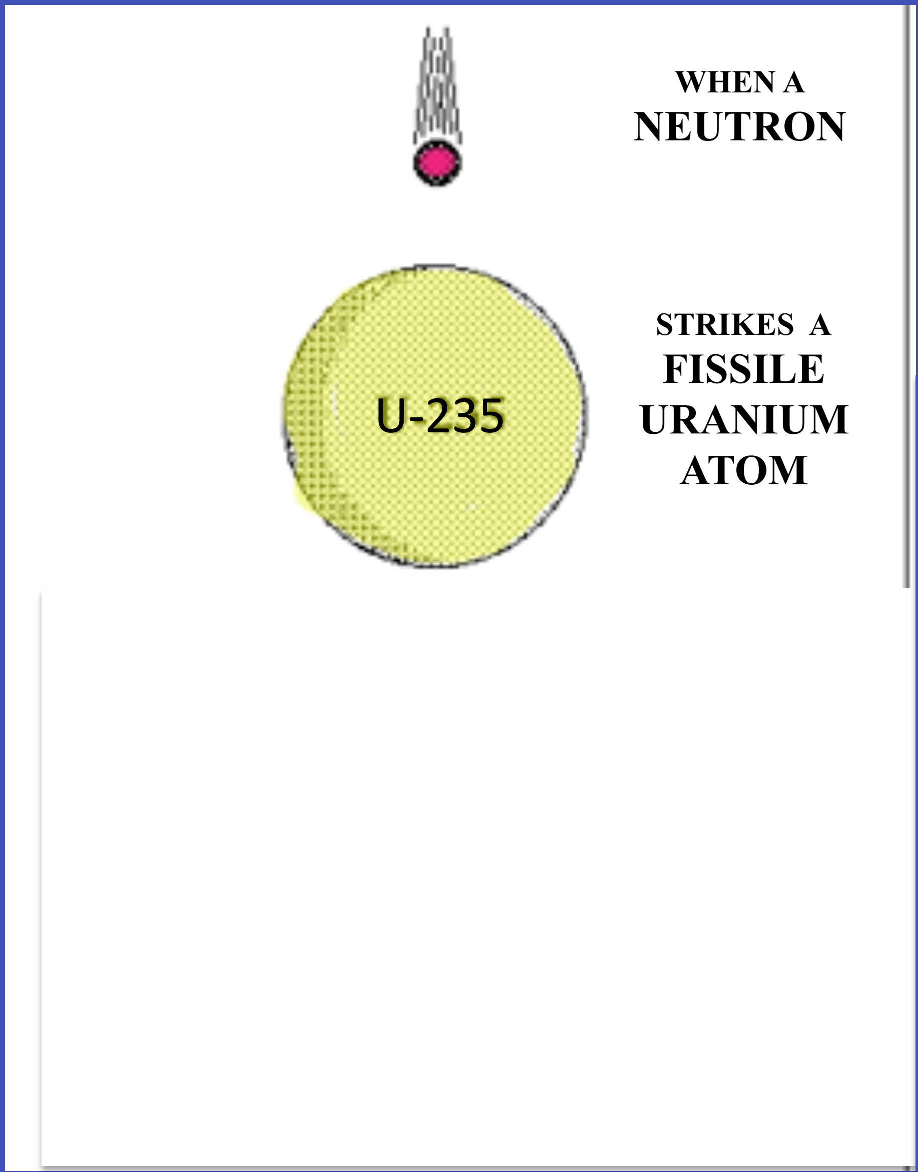
Battlefield explosion

Forest fire

. . . **but nuclear energy** comes from the nucleus – and it is **millions of times more powerful**

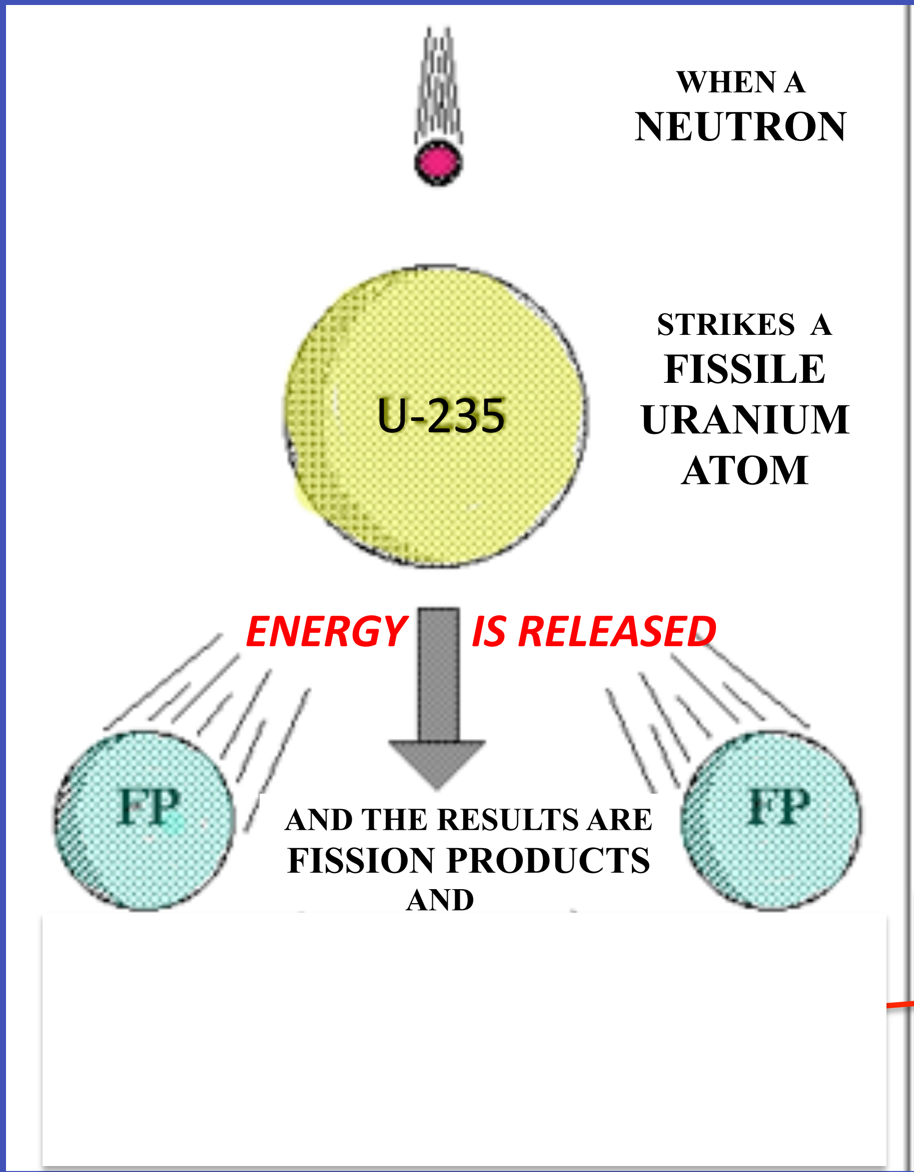
H-Bomb Blast

Nuclear Fission



A subatomic projectile called a neutron starts a nuclear chain reaction by splitting a nucleus of "fissile uranium" (U-235).

Nuclear Fission

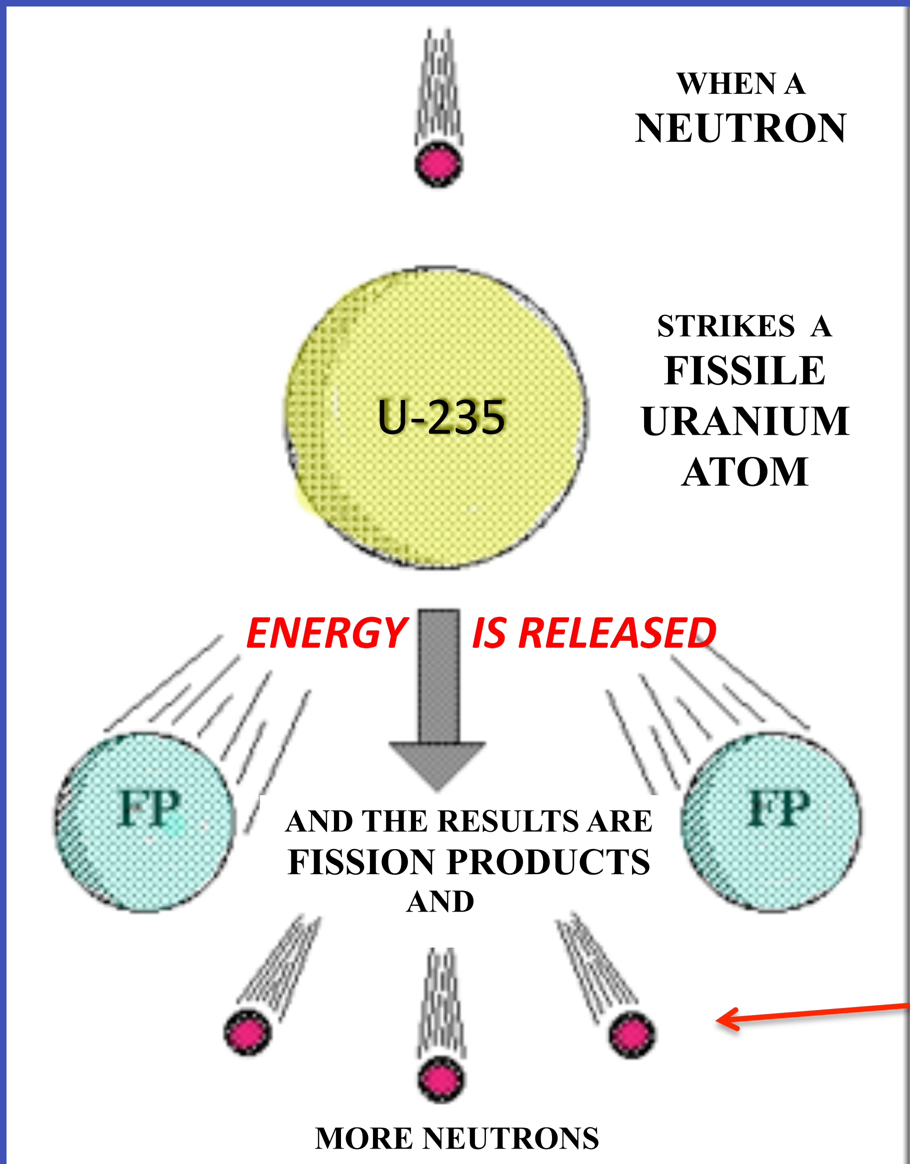


A subatomic projectile called a neutron starts a nuclear chain reaction by splitting a nucleus of "fissile uranium" (U-235).

The nucleus splits into two large fragments and energy is released – along with 2 or 3 extra neutrons.

The 2 broken pieces are new radioactive nuclei called "fission products".

Nuclear Fission



A subatomic projectile called a neutron starts a nuclear chain reaction by splitting a nucleus of "fissile uranium" (U-235).

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The 2 broken pieces are new radioactive nuclei called "fission products".

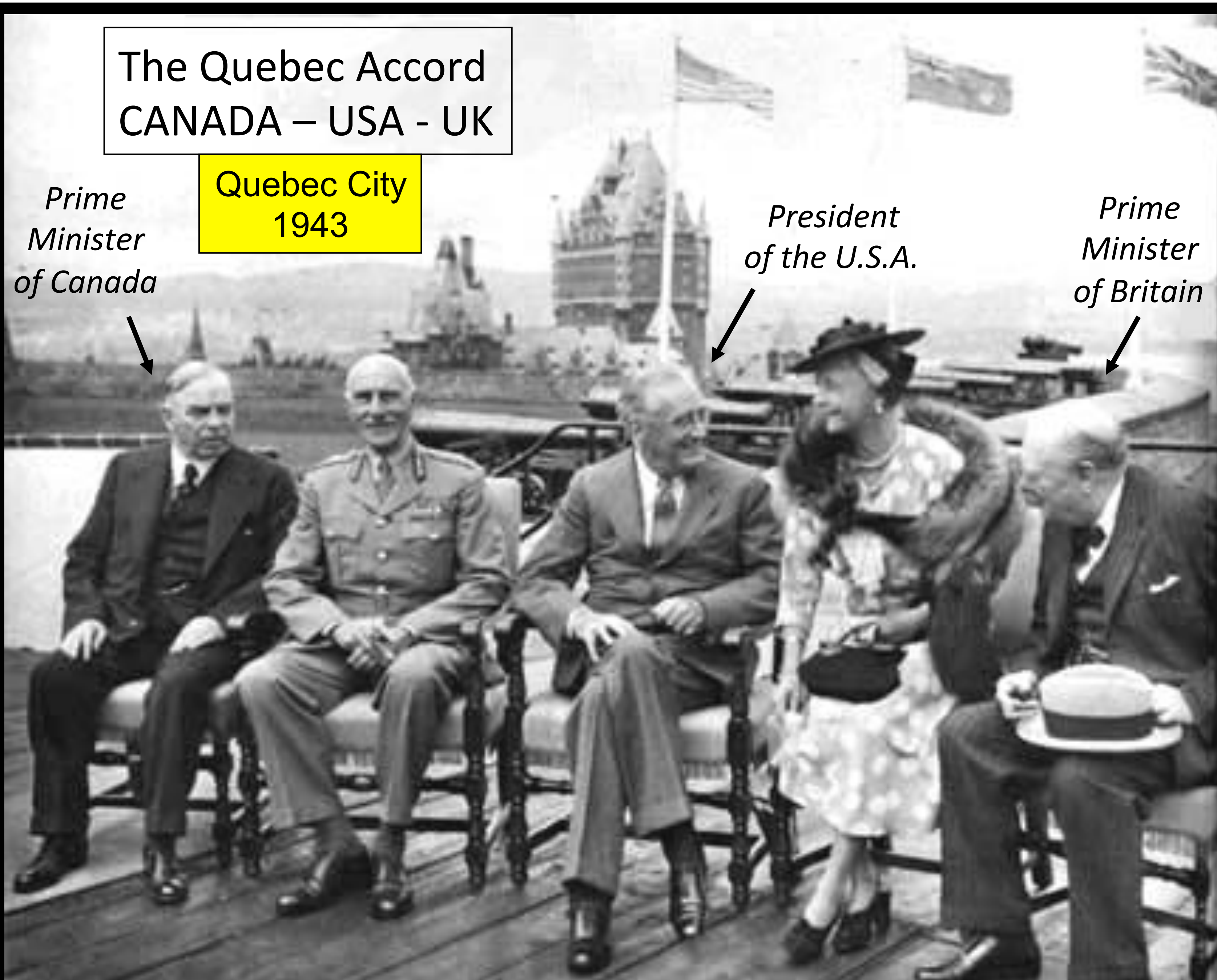
Extra neutrons trigger more fissions and so the energy release is multiplied enormously.

Uranium-235
is the only material found
in nature that can sustain
a nuclear chain reaction.

Plutonium, which is a
Uranium derivative,
can do likewise.

Uranium that has a
higher-than-usual
concentration of U-235
is said to be “enriched”.


URANIUM BOMB
used highly enriched uranium
Destruction of Hiroshima caused by a Uranium Bomb, on August 6, 1945



Canada agreed to supply uranium for the WWII Atomic Bomb Project

The Hiroshima Bomb was made of

very highly enriched uranium (HEU)

called "weapons-grade uranium"

[over 90 percent U-235]

The Chalk River targets are also made of weapons-grade uranium

[93.3 percent U-235]

So we have: (1) Risk of hijackers; (2) Armed escorts; (3) Great secrecy; (4) Danger of Accidental Criticality (Spontaneous Nuclear Chain Reaction)

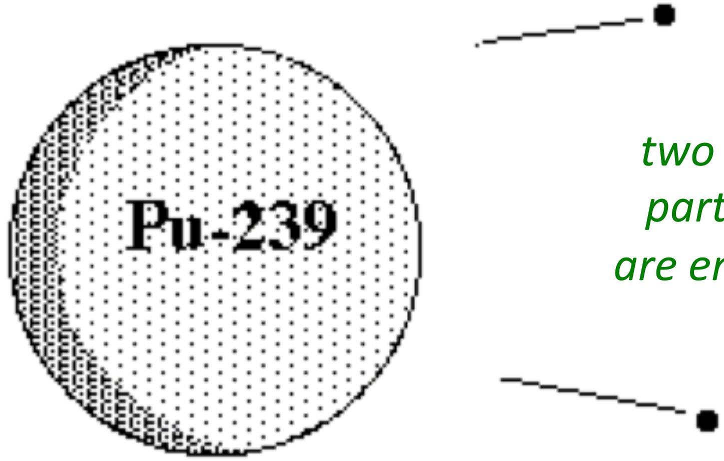
A "criticality accident"
is a burst of neutron radiation
caused by a nuclear chain reaction.

Neutrons are highly penetrating
and highly damaging to living cells.

Criticality can only occur with
enriched uranium
or plutonium.

Creation of plutonium inside a nuclear reactor …

. . . when an atom of uranium-238 absorbs a neutron



. . . it is transformed into an atom of plutonium-239

Other transuranic actinides are produced in a similar way.

Bronze Plaque at
Chalk River Visitors' Centre

Photo: Robert Del Tredici

THE ZEEP REACTOR

A nuclear chain reaction was first initiated in Canada on September 5, 1945, when the ZEEP reactor went into operation here at Chalk River. Originally part of an effort to produce plutonium for nuclear weapons, the reactor was designed by a team of Canadian, British and French scientists and engineers assembled in Montreal and in Ottawa in 1942-43 under the administration of the National Research Council. Named Zero Energy Experimental Pile because it was developed to produce only one watt of heat, the ZEEP reactor was used to provide data for the design of the powerful NRX (National Research Experimental) reactor. In 1952 the project was transferred from NRC to Atomic Energy of Canada Limited.

Part 3 : Radioactivity

Nuclear Energy

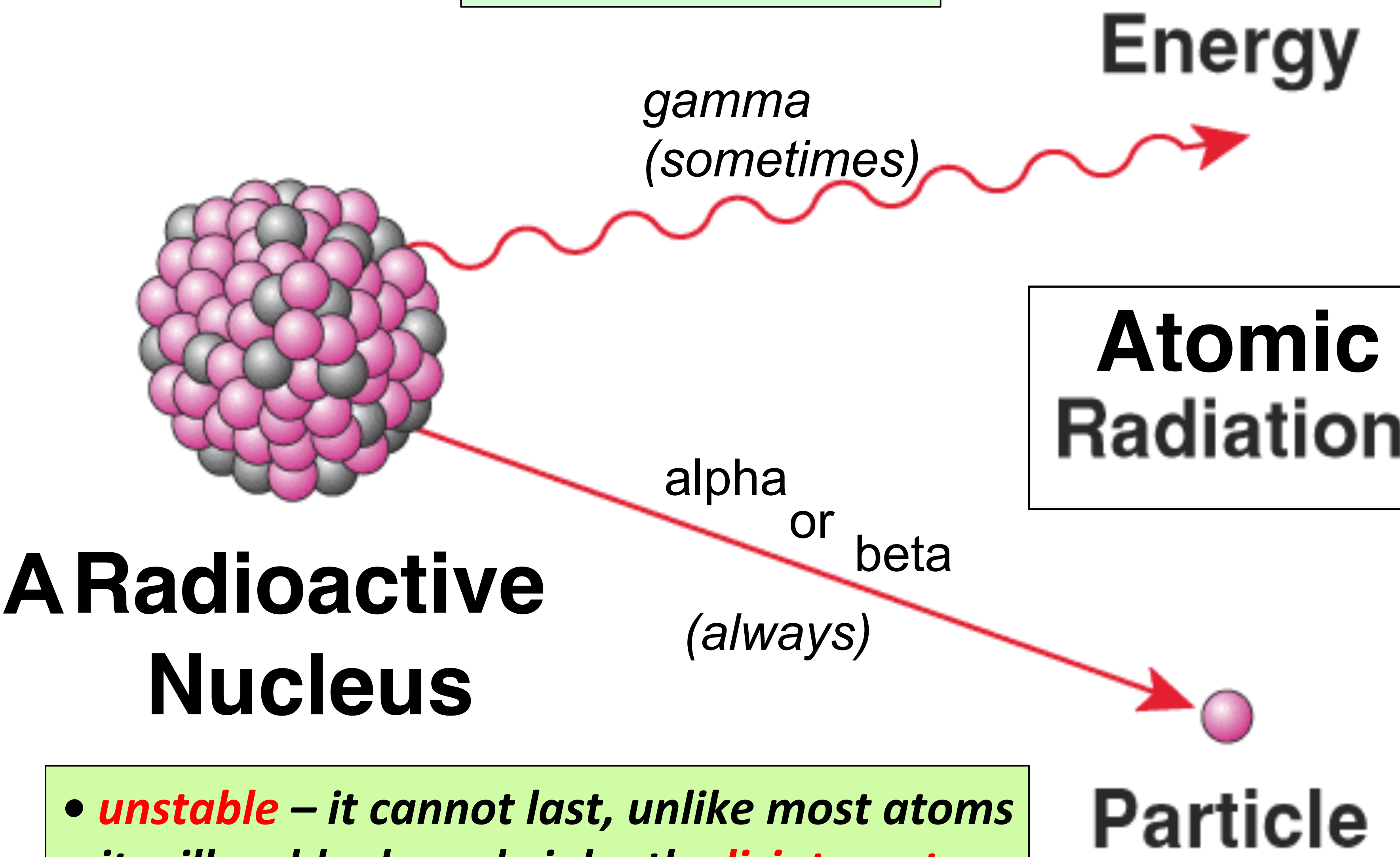
~ two types ~

1. Nuclear Fission (known for 78 years)

2. Radioactivity (known for 121 years)

1896: Discovery of radioactivity.
1938-39: Discovery of nuclear fission.

Radioactivity



- ***unstable* – it cannot last, unlike most atoms**
- ***it will suddenly and violently disintegrate***

Alpha, Beta, and Gamma “rays” are normally invisible

But in a “cloud chamber” you can see the tracks of all 3 types of emissions from uranium ore

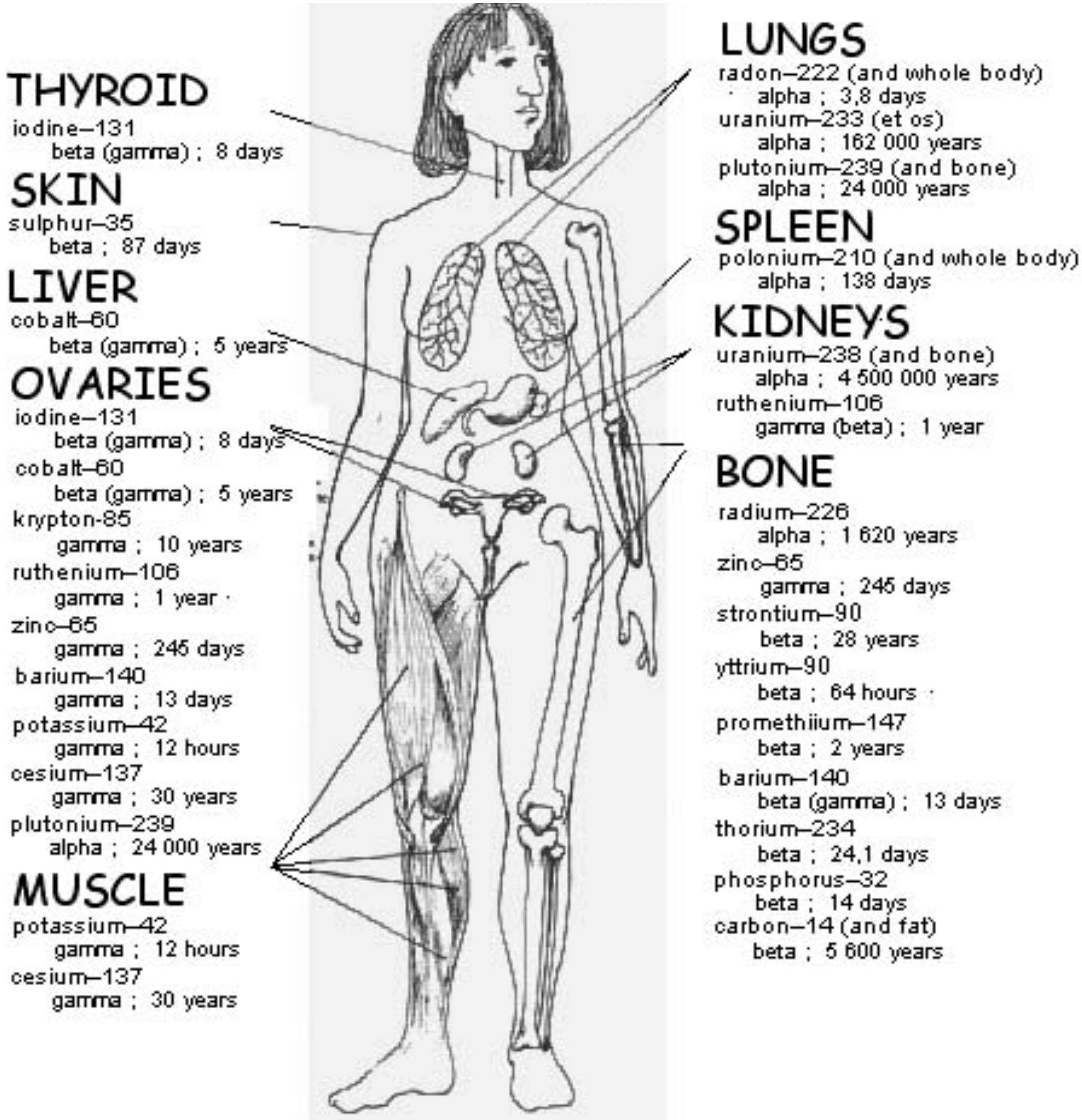
Radioactivity is

a form of nuclear energy

that cannot be shut off.

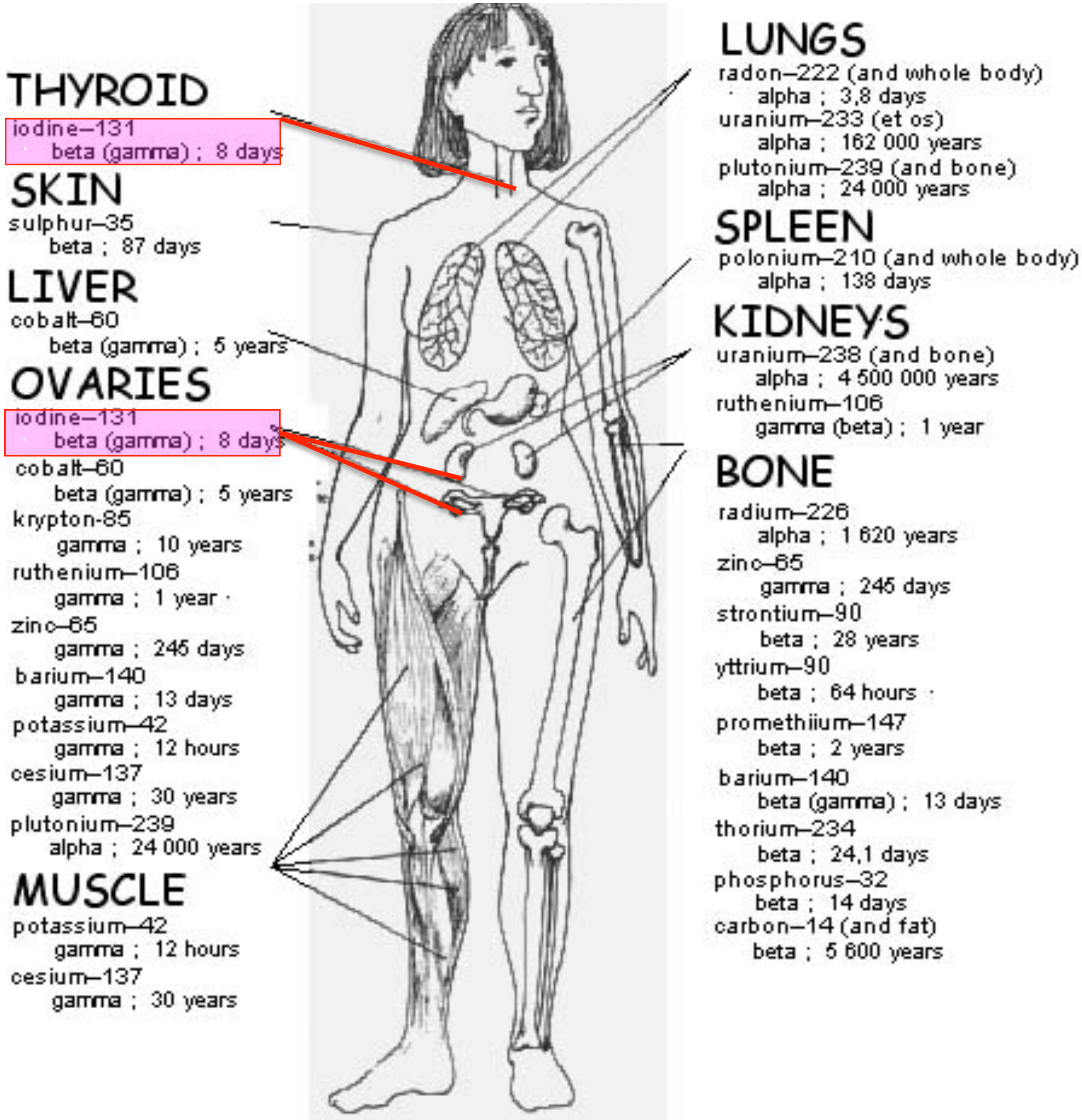
That's why we have
a nuclear waste problem.

RADIOACTIVE MATERIALS



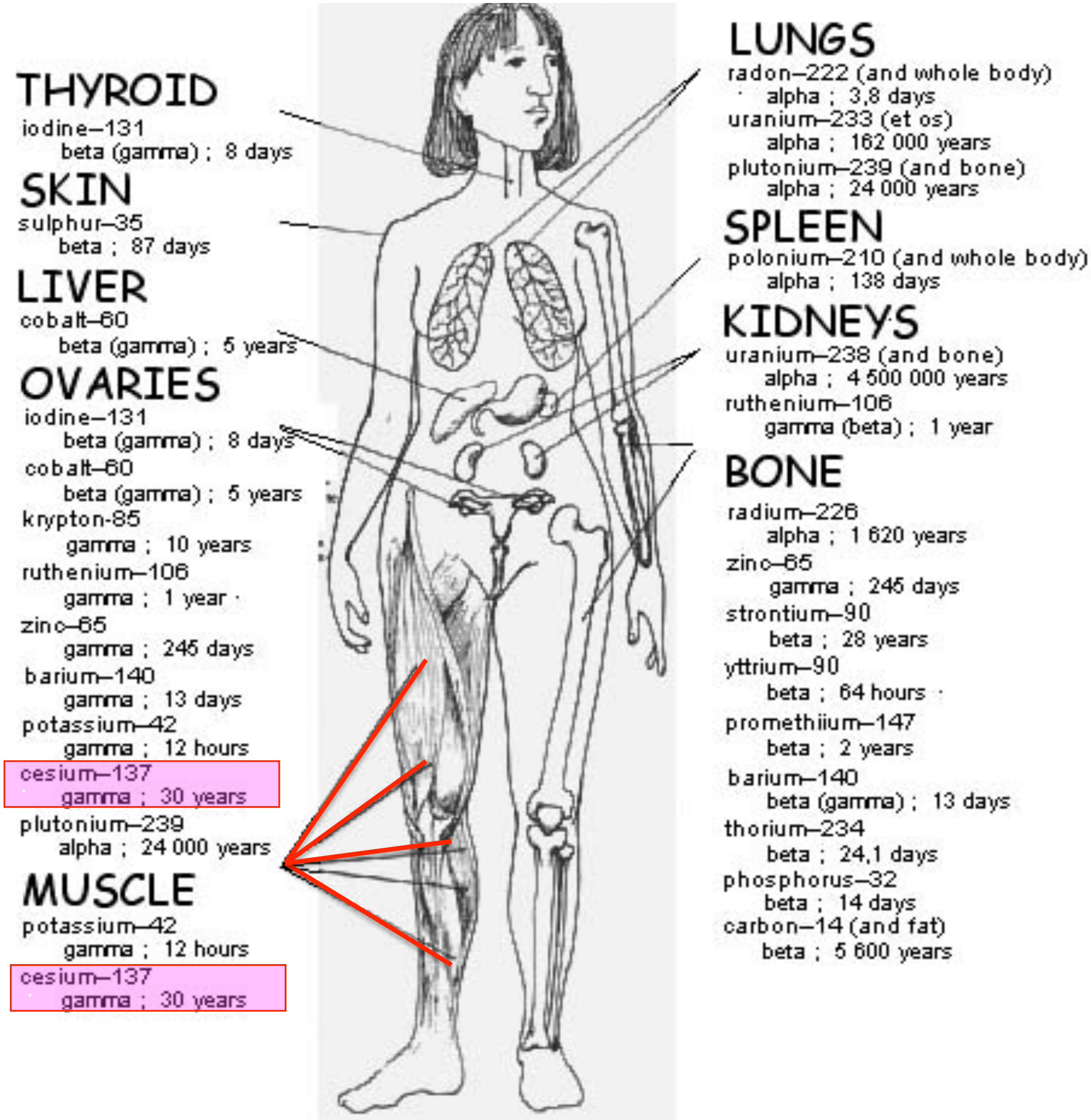
Fission Products are chemical substances which are also radioactive.

RADIOACTIVE MATERIALS



Iodine-131 goes to the thyroid gland (in the throat) and damages it.

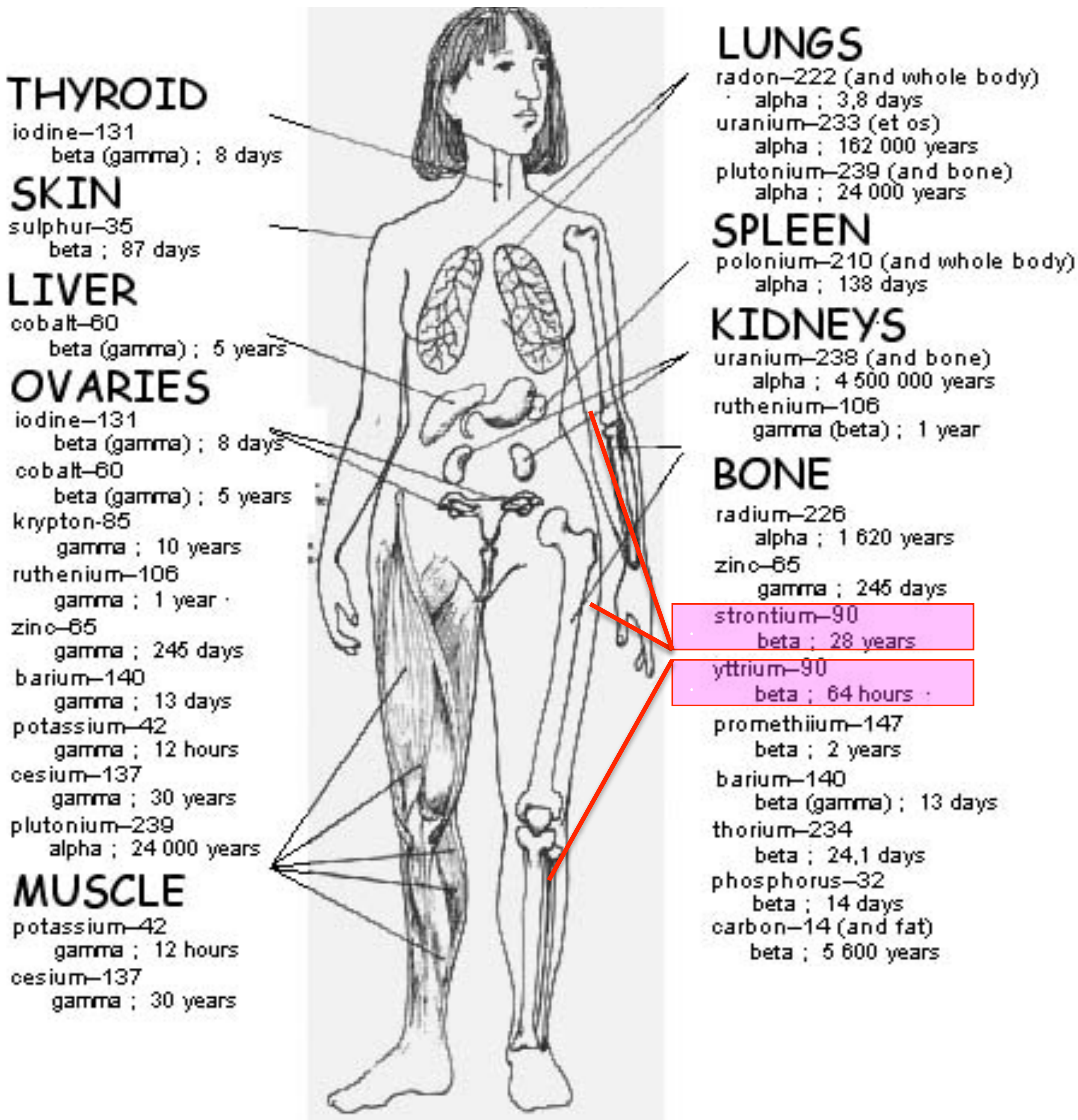
RADIOACTIVE MATERIALS



Cesium-137 goes to the soft tissues

(makes meat unfit as food)

RADIOACTIVE MATERIALS

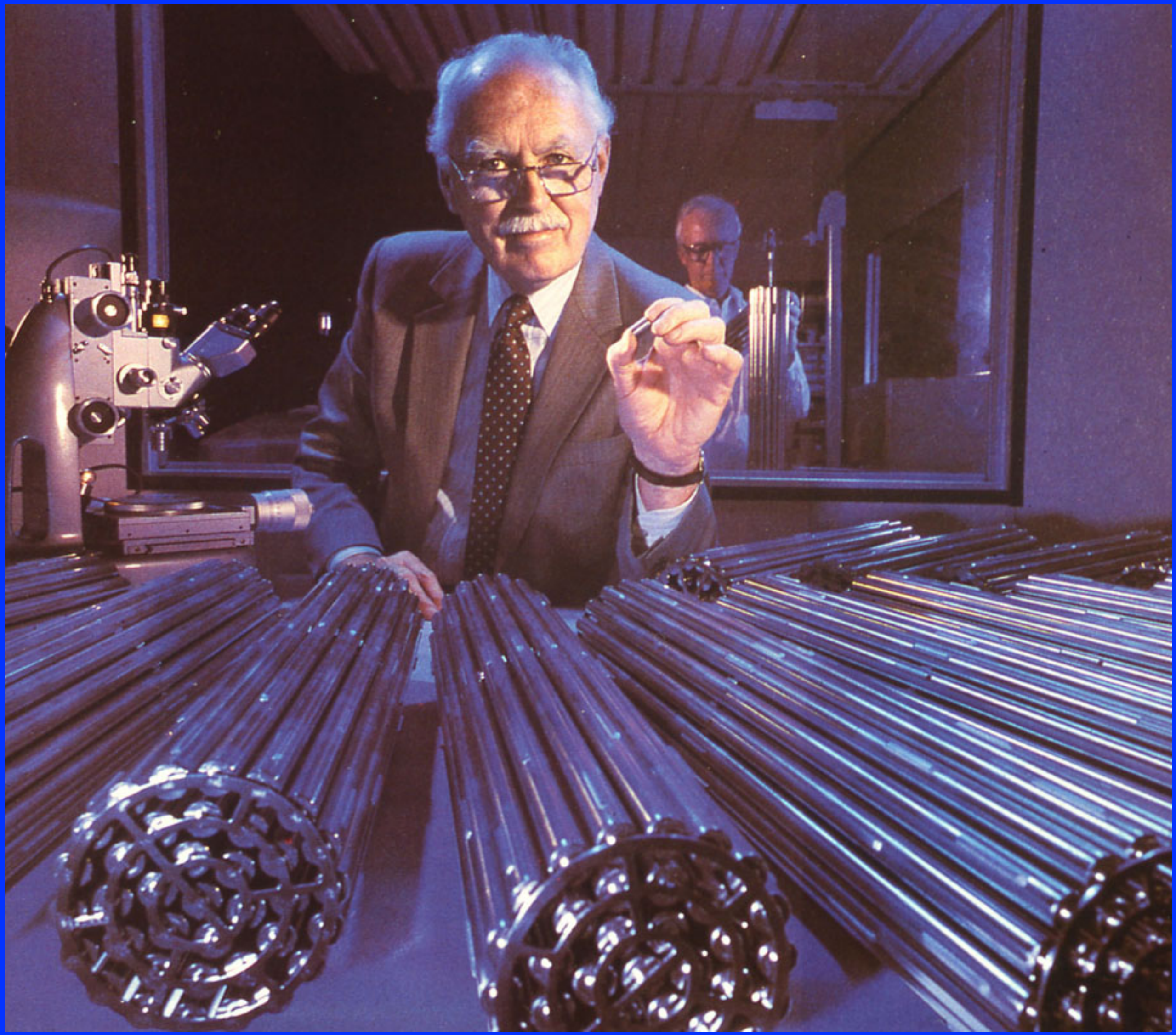


Strontium-90 behaves like calcium; it goes to the bones, the teeth and mother´s milk.

Chronic exposure to atomic radiation
increases the incidence of
cancer, leukemia, genetic damage,
strokes, heart attacks, & low intelligence

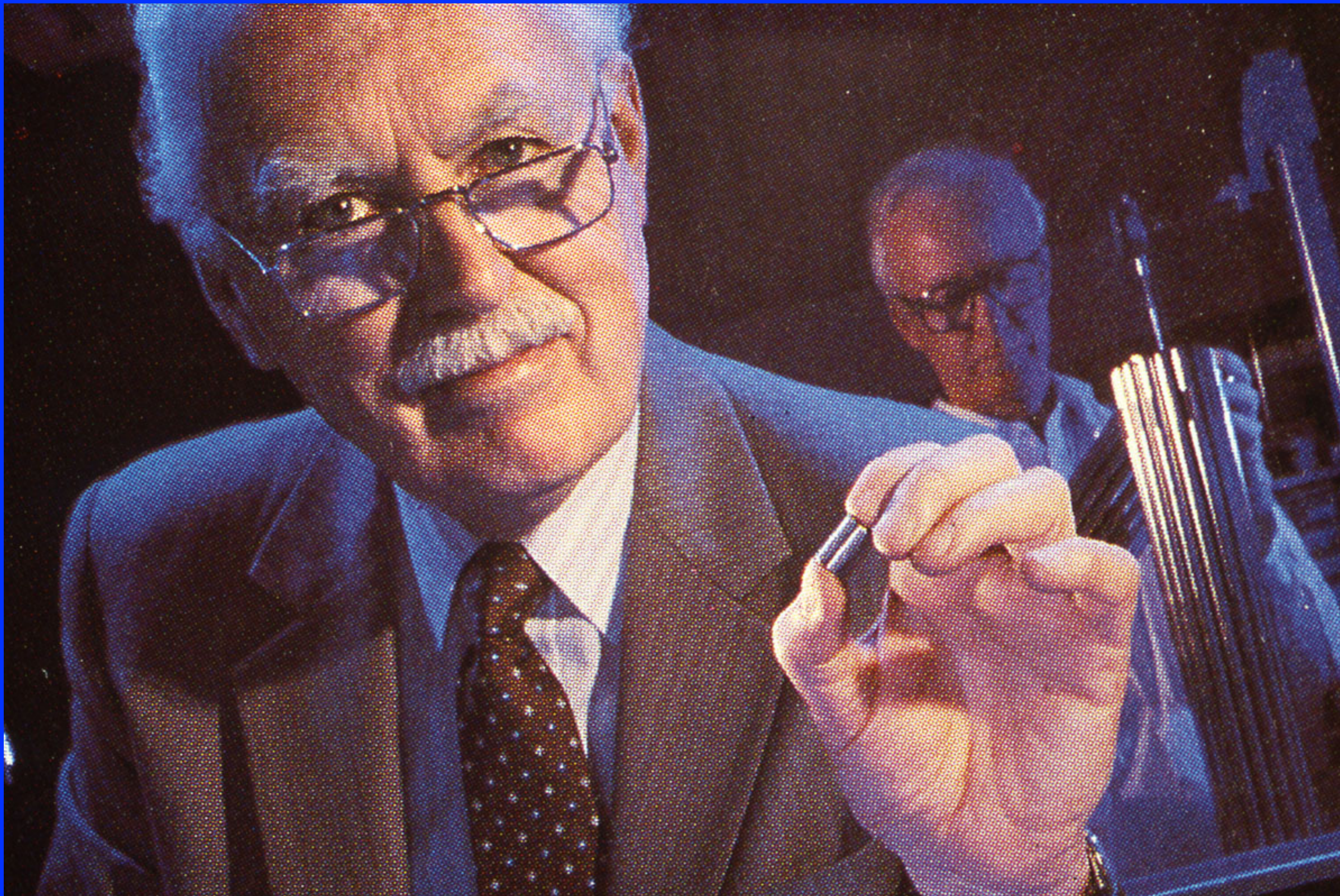
BUT there is a "latency period"
for exposure at low levels

– the onset of disease occurs years
or decades after exposure.



Nuclear fuel rods and pellets can be handled safely before use,
Once used, the fission products will deliver a lethal dose of radiation in seconds.

"Small Wonder" : Canadian Nuclear Association Ad



Canadian Nuclear Association ad: ´Small Wonder´

Three “sources” of nuclear waste materials:

1. Fission Products (e.g. cesium-137, iodine-131)

   ~ the broken bits of uranium atoms
   (lighter atoms ~ 1/3 to 2/3 the size of U)

2. Transuranics (Actinides) (e.g. plutonium, americium)

   ~ heavier-than-uranium elements that are
   created when uranium absorbs neutrons

3. Activation Products (e.g. cobalt-60, carbon-14)

   ~ transmuted versions of non-radioactive atoms
   that are “activated” by absorbing stray neutrons

These three categories are differentiated in the table of radionuclides that follows.

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

F.I.A.P. = fuel impurity activation product   Z.A.P. = zirconium cladding activation product   [source: AECL]

Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
H (T)	Hydrogen (Tritium)	3	¥¥¥	¥	¥	
Be	Beryllium	10		¥	¥	
C	Carbon	14		¥¥¥	¥¥¥	
Si	Silicon	32		¥	¥	
P	Phosphorus	32		¥	¥	
S	Sulphur	35		¥		
Cl	Chlorine	36		¥		
Ar	Argon	39		¥	¥	
Ar	Argon	42		¥	¥	
K	Potassium	40		¥		
K	Potassium	42			¥	
Ca	Calcium	41		¥		
Ca	Calcium	45			¥	
Sc	Scandium	46		¥		
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
V	Vanadium	50			¥	
Mn	Manganese	54		¥	¥¥¥	
Fe	Iron	55		¥¥¥	¥¥¥	
Fe	Iron	59			¥	
Co	Cobalt	58		¥	¥	
Co	Cobalt	60		¥¥¥	¥¥¥	
Ni	Nickel	59		¥	¥¥¥	
Ni	Nickel	63		¥¥¥	¥¥¥	
Zn	Zinc	65		¥	¥	
Se	Selenium	79	¥¥¥			
Kr	Krypton	81	¥			
Kr	Krypton	85	¥¥¥			
Rb	Rubidium	87	¥			
Sr	Strontium	89	¥		¥	
Sr	Strontium	90	¥¥¥	¥	¥	
Y	Yttrium	90	¥¥¥	¥	¥	

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

Y	Yttrium	91	¥		¥	
Zr	Zirconium	93	¥¥¥	¥	¥¥¥	
Zr	Zirconium	95	¥	¥	¥	
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Nb	Niobium	92			¥	
Nb	Niobium	93m	¥¥¥	¥	¥¥¥	
Nb	Niobium	94	¥	¥	¥¥¥	
Nb	Niobium	95	¥	¥	¥	
Nb	Niobium	95m	¥		¥	
Mo	Molybdenum	93		¥	¥	
Tc	Technetium	99	¥¥¥	¥	¥	
Ru	Ruthenium	103	¥			
Ru	Ruthenium	106	¥¥¥			
Rh	Rhodium	103m	¥			
Rh	Rhodium	106	¥¥¥			
Pd	Palladium	107	¥¥¥			
Ag	Silver	108	¥	¥	¥	
Ag	Silver	108m	¥	¥¥¥	¥	
Ag	Silver	109m	¥	¥	¥	
Ag	Silver	110	¥	¥	¥	
Ag	Silver	110m	¥	¥	¥	
Cd	Cadmium	109	¥	¥	¥	
Cd	Cadmium	113	¥		¥	
Cd	Cadmium	113m	¥¥¥		¥	
Cd	Cadmium	115	¥			
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
In	Indium	113m			¥	
In	Indium	114	¥	¥	¥	
In	Indium	114m			¥	
In	Indium	115			¥	
Sn	Tin	113			¥	
Sn	Tin	117m	¥	¥	¥	
Sn	Tin	119m	¥¥¥		¥¥¥	
Sn	Tin	121m	¥		¥¥¥	
Sn	Tin	123	¥		¥	

F.I.A.P. = fuel impurity activation product *Z.A.P. = zirconium cladding activation product* *[source: AECL]*

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

Sn	Tin	125	¥¥¥		¥	
Sn	Tin	126				
Sb	Antimony	124	¥		¥	
Sb	Antimony	125	¥¥¥		¥¥¥	
Sb	Antimony	126	¥		¥	
Sb	Antimony	126m	¥¥¥			
Te	Tellurium	123	¥		¥	
Te	Tellurium	123m	¥		¥	
Te	Tellurium	125m	¥¥¥		¥¥¥	
Te	Tellurium	127	¥		¥	
Te	Tellurium	127m	¥		¥	
I	Iodine	129	¥		¥	
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Cs	Cesium	134	¥			
Cs	Cesium	135	¥¥¥			
Cs	Cesium	137	¥¥¥			
Ba	Barium	137m	¥¥¥			
La	Lanthanum	138	¥			
Ce	Cerium	142	¥			
Ce	Cerium	144	¥¥¥			
Pr	Praseodymium	144	¥¥¥			
Pr	Praseodymium	144m	¥¥¥			
Nd	Neodymium	144	¥			
Pm	Promethium	147	¥¥¥			
Sm	Samarium	147	¥			
Sm	Samarium	148	¥	¥		
Sm	Samarium	149	¥			
Sm	Samarium	151	¥¥¥			
Eu	Europium	152	¥¥¥	¥		
Eu	Europium	154	¥¥¥	¥		
Eu	Europium	155	¥¥¥	¥		
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Gd	Gadolinium	152	¥	¥		
Gd	Gadolinium	153	¥	¥		
Tb	Terbium	157		¥		

F.I.A.P. = fuel impurity activation product   Z.A.P. = zirconium cladding activation product   [source: AECL]

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

Tb	Terbium	160		¥		
Dy	Dysprosium	159		¥		
Ho	Holmium	166m	¥	¥		
Tm	Thulium	170		¥		
Tm	Thulium	171		¥		
Lu	Lutetium	176			¥	
Lu	Lutetium	176			¥	
Lu	Lutetium	176			¥	
Hf	Hafnium	175			¥	
Hf	Hafnium	181			¥	
Hf	Hafnium	182			¥	
Ta	Tantalum	180			¥	
Ta	Tantalum	182			¥	
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
W	Tungsten	181			¥	
W	Tungsten	185			¥	
W	Tungsten	188			¥	
Re	Rhenium	187			¥	
Re	Rhenium	188			¥	
Os	Osmium	194			¥	
Ir	Iridium	192			¥	
Ir	Iridium	192m			¥	
Ir	Iridium	194			¥	
Ir	Iridium	194m			¥	
Pt	Platinum	193			¥	
Tl	Thallium	206			¥	
Tl	Thallium	207				¥
Tl	Thallium	208				¥
Tl	Thallium	209				¥
Pb	Lead	204			¥	
Pb	Lead	205			¥	
Pb	Lead	209				¥
Pb	Lead	210				¥
Pb	Lead	211				¥
Pb	Lead	212				¥
Pb	Lead	214				¥
Standard	Common Name of	Atomic Mass	F.P.	F.I.A.P.	Z.A.P.	Actinide

F.I.A.P. = fuel impurity activation product   Z.A.P. = zirconium cladding activation product   [source: AECL]

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

Chemical Symbol	element	Number	Fission Product	Activation Product	Activation Product	(includes progeny)
Bi	Bismuth	208			¥	
Bi	Bismuth	210			¥	¥
Bi	Bismuth	210m				¥
Bi	Bismuth	211				¥
Bi	Bismuth	212				¥
Bi	Bismuth	213				¥
Bi	Bismuth	214				
Po	Polonium	210			¥	¥
Po	Polonium	211				¥
Po	Polonium	212				¥
Po	Polonium	213				¥
Po	Polonium	214				¥
Po	Polonium	215				¥
Po	Polonium	216				¥
Po	Polonium	218				¥
At	Astatine	217				¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Rn	Radon	219				¥
Rn	Radon	220				¥
Rn	Radon	222				¥
Fr	Francium	221				¥
Fr	Francium	221				¥
Ra	Radium	223				¥
Ra	Radium	224				¥
Ra	Radium	225				¥
Ra	Radium	226				¥
Ra	Radium	228				¥
Ac	Actinium	225				¥
Ac	Actinium	227				¥
Ac	Actinium	228				¥
Th	Thorium	227				¥
Th	Thorium	228				¥
Th	Thorium	229				¥
Th	Thorium	230				¥
Th	Thorium	231				¥
Th	Thorium	232				¥

F.I.A.P. = fuel impurity activation product   Z.A.P. = zirconium cladding activation product   [source: AECL]

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

Th	Thorium	234				¥¥¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Pa	Protactinium	231				¥
Pa	Protactinium	233				¥¥¥
Pa	Protactinium	234				¥
Pa	Protactinium	234m				¥¥¥
U	Uranium	232				¥
U	Uranium	233				¥
U	Uranium	234				¥¥¥
U	Uranium	235				¥
U	Uranium	236				¥¥¥
U	Uranium	237				¥¥¥
U	Uranium	238				¥¥¥
U	Uranium	240				¥
Np	Neptunium	237				¥¥¥
Np	Neptunium	238				¥
Np	Neptunium	239				¥¥¥
Np	Neptunium	240				¥
Np	Neptunium	240m				¥
Pu	Plutonium	236				¥
Pu	Plutonium	238				¥¥¥
Pu	Plutonium	239				¥¥¥
Pu	Plutonium	240				¥¥¥
Pu	Plutonium	241				¥¥¥
Pu	Plutonium	242				¥¥¥
Pu	Plutonium	243				¥
Pu	Plutonium	244				¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Am	Americium	241				¥¥¥
Am	Americium	242				¥¥¥
Am	Americium	242m				¥¥¥
Am	Americium	243				¥¥¥
Am	Americium	245				¥
Cm	Curium	242				¥¥¥
Cm	Curium	243				¥¥¥

F.I.A.P. = fuel impurity activation product Z.A.P. = zirconium cladding activation product [source: AECL]

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

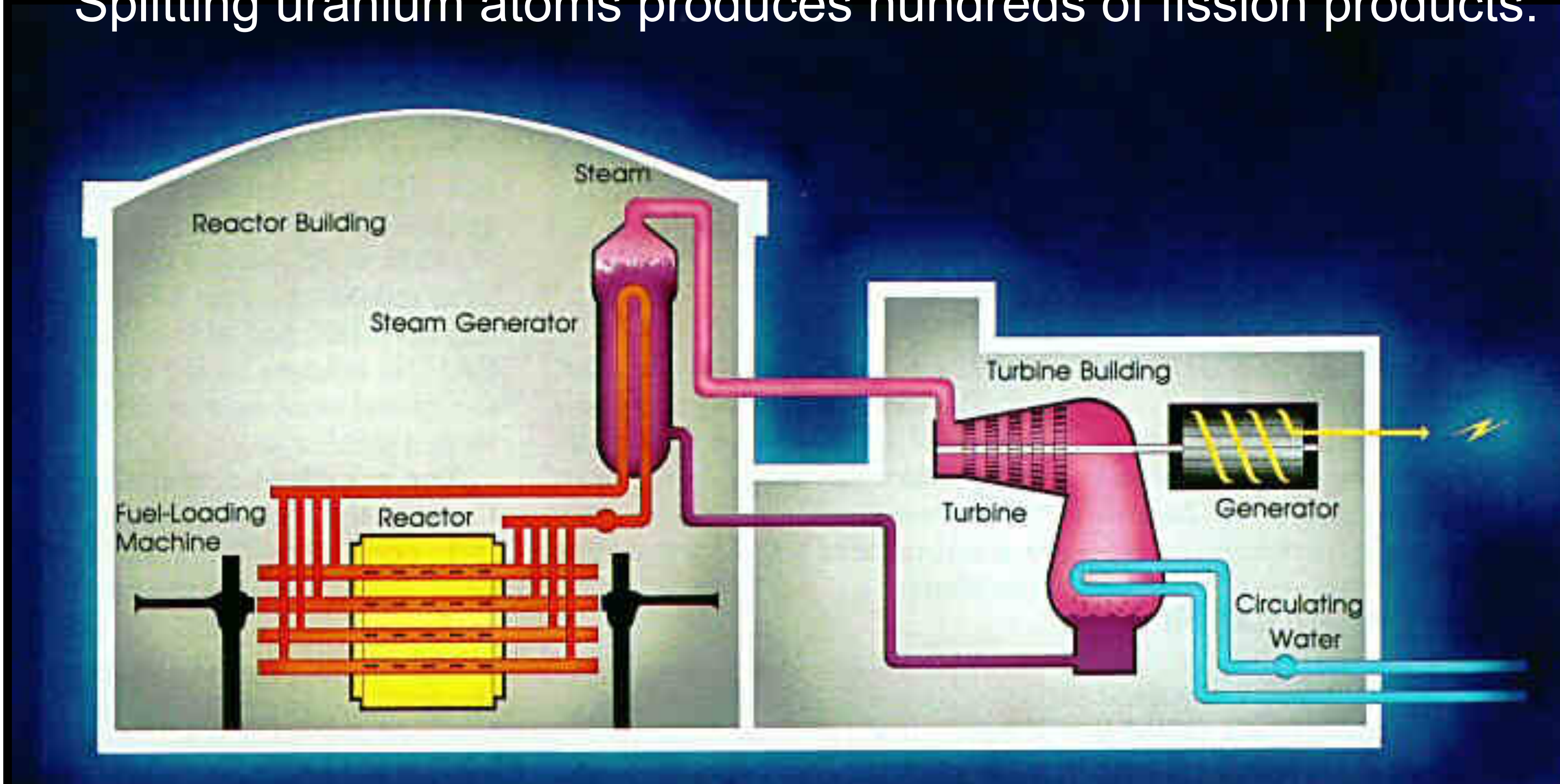
Cm	Curium	244				¥¥¥
Cm	Curium	245				¥
Cm	Curium	246				¥
Cm	Curium	247				¥
Cm	Curium	248				¥
Cm	Curium	250				¥
Bk	Berkelium	249				¥
Bk	Berkelium	250				¥
Cf	Californium	249				¥
Cf	Californium	250				¥
Cf	Californium	251				¥
Cf	Californium	252				¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)

F.I.A.P. = fuel impurity activation product Z.A.P. = zirconium cladding activation product [source: AECL]

This list of 211 man-made radionuclides contained in irradiated nuclear fuel is by no means complete! (AECL)

[AECL = Atomic Energy of Canada Limited]

The CANDU reactor is a "Pressurized Heavy Water Reactor"
Splitting uranium atoms produces hundreds of fission products.



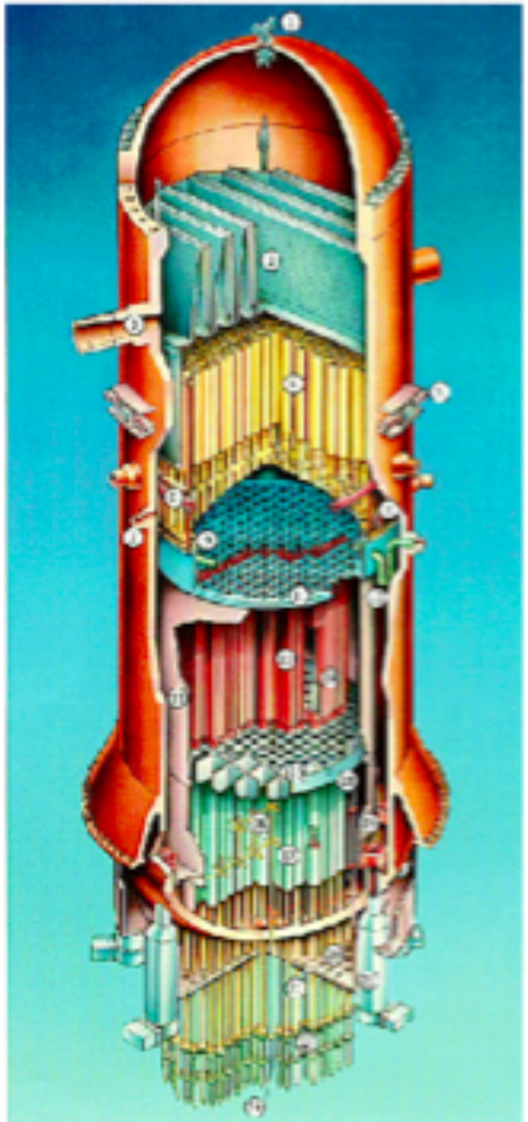
Heat from the core goes to the Steam Generator (Boiler).

The steam spins a turbine and generates lots of electricity.

Everything in the red "primary cooling circuit" is very radioactive.

Nuclear Intestines

Inside each of the old steam generators from Bruce reactors are 4200 radioactively contaminated tubes, similar to those shown here.



Plutonium in the Bruce "A" nuclear steam generators

Here is a partial list of radioactive contaminants inside a single used steam generator from each one of the two reactors (Units 1 and 2 of Bruce A), according to CNSC (document CMD-10-H19B). The mass (in grams) of each of the radioactive materials listed is estimated by CNSC staff.

RADIONUCLIDE		***MASS***	
Name of Isotope (with Atomic Mass)	Half-Life (years)	Unit 1 (grams radioactive material)	Unit 2
Americium-241	430 y	0.103412	0.102412
Americium-243	7 400 y	0.002162	0.002432
Carbon-14	5 700 y	0.009065	0.072501
Curium-244	18 y	0.002644	0/000347
Cobalt-60	5.3 y	0.001781	0/000881
Cesium-137	30 y	0/000249	0.000238
Europium-154	8.8 y	0.000027	0.000290
Iron-55	2.7 y	0.000272	0.000290
Hydrogen-3 (Tritium)	13.0 y	0.000057	0.000051
Hafnium-181	2.7 y	0.000001	0.000001
Iodine-129	17 000 000 y	0.000060	0.000060
Niobium-94	20 000 y	0.002159	0.002158
Nickel-59	75 000 y	0.173601	0.036723
Nickel-63	96 y	0.030194	0.006526
Neptunium-237	2 100 000 y	0.028703	0.033295
Plutonium-238	*88 y*	*0.007507*	*0.004703*
Plutonium-239	*24 000 y*	*2.124977*	*2.471769*
Plutonium-240	*6 500 y*	*0.827304*	*0.957105*
Plutonium-241	*14 y*	*0.021309*	*0.030809*
Plutonium-242	*380 000 y*	*0.048762*	*0.056317*
Antimony-125	2.8 y	0.000001	0.000001
Strontium-90	29 y	0.009097	0.007581
Technetium-99	210 000 y	0.000143	0.000092
TOTALS			
Long-lived (> one year half-life)		**3.416108**	**3.787315**
Mass of plutonium isotopes only		**3.029859**	**3.520703**
Percent plutonium		**88.7%**	**93.0%**
	TOTAL MASS		
		(Source: CNSC)	

There are 5 plutonium isotopes present in the steam generators.
In addition there are 18 other long-lived isotopes listed.

Inside each steam generator:

8 radionuclides	half-lives	>1,000,000 years
13 radionuclides	half-lives	>100,000 years
19 radionuclides	half-lives	>1,000 years
21 radionuclides	half-lives	>100 years

Includes 5 different varieties of plutonium.

There are about 18 grams of plutonium-239 in

8 Bruce steam generators (from one reactor).

In principle, that

is enough to overdose

over 25 million atomic workers

FREE RELEASE OF NUCLEAR WASTE

“recycling of contaminated metal”

To reduce its nuclear waste volume, Bruce Power planned to ship 16 radioactive steam generators (from 2 of its 8 reactors) to Sweden, for Studsvik to “recycle” the contaminated metal.

During public hearings Studsvik said the contaminated metal would go to another company they would not name, who would blend it in a 1 to 10 ratio with uncontaminated metal. The blend is then sold, without labelling, as “clean” scrap metal suitable for unrestricted use. This practice is called ‘free release’.

Hundreds of municipalities in Canada and the USA passed resolutions opposing this plan, whereby man-made nuclear waste products would end up in consumer goods. First Nations also expressed strong opposition to the proposed transport.

THE SHIPMENTS WERE STOPPED

the steam generators remain on-site

Although Bruce Power obtained all necessary approvals to proceed with the shipments, the steam generators never went to Sweden – because of massive public opposition.

The industry said it was "recycling contaminated metal". Others saw the project as "contaminating recycled metal".

"contamination of recycled metal"

The Steel Manufacturing Association strongly opposes any radioactive contamination of recycled metal, and the UN declares the practice to be an alarming one.

Yet "free release" is already occurring in Europe because the population is "asleep at the switch". People need to be alert.

Part 4 : Toxicity of Liquid

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)

SYMBOLS AND NUMBERS ARE ALMOST INCOMPREHENSIBLE TO THE LAY PERSON

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		

AND . . .
only 28 radionuclides are listed

BY CONTRAST THERE ARE 123 RADIONUCLIDES LISTED IN AN AECL DOCUMENT

This table, incomplete as it is, shows that the radioactivity of the liquid is more than 16,000 times greater than the radioactivity of the uranium content alone.

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

HERE THE NAMES AND NUMBERS ARE A BIT MORE "READABLE"

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

Isotope	Becquerels per litre
Niobium-95	6.6 billion
Niobium-95m	25 billion
Zirconium-95	25 billion
Rhodium-103m	18 billion
Ruthenium-103	18 billion
Rhodium-106	546 million
Ruthenium-106	546 million
Iodine-131	19 billion
Xenon-131m	19 billion
Tellurium-132	10 billion

Isotope	Becquerels per litre
Beryllium-137m	70 billion
Cesium-137	70 billion
Barium-140	58 billion
Lanthanum-140	58 billion
Cerium-141	43 billion
Cerium-144	8 billion
Praseodymium-144	8 billion
Praseodymium-144m	8 billion
Neodymium-147	15 billion
Europium-154	84 million

Isotope	Becquerels per litre
Europium-155	195 million
Uranium-234	28 million
Uranium-235	559 thousand
Uranium-236	366 thousand
Uranium-238	6 thousand
Neptunium-237	4 thousand
Plutonium-239	1 million
Plutonium-240	9 thousand

GAMMA EMITTERS IN BLUE
ACTINIDES ARE IN RED

YOU CAN SEE THE RADIOACTIVITY OF URANIUM IS JUST A TINY FRACTION OF THE TOTAL

476 billion becquerels per litre for gamma emitters
> 16 THOUSAND x (29 million becquerels per litre for uranium)

What is an Actinide?

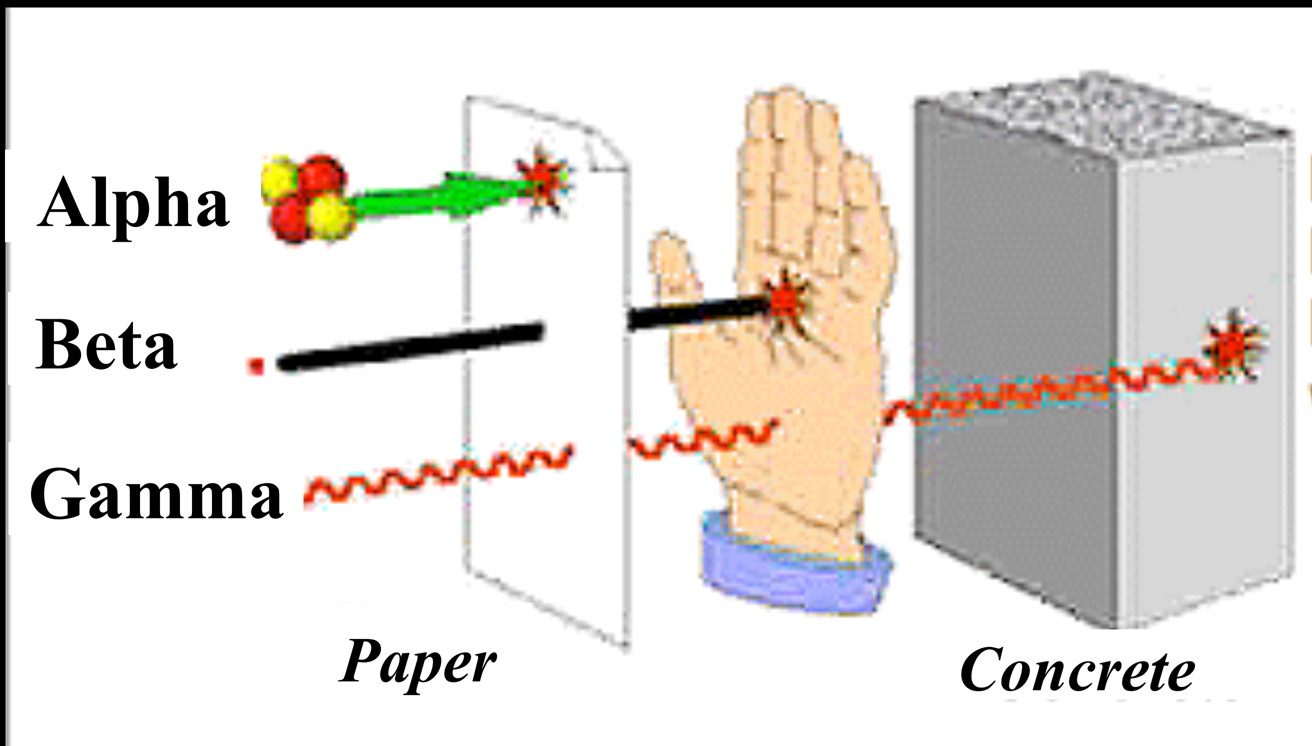
Actinides are heavy elements. They include uranium, thorium, and transuranic elements.

Most actinides are “alpha-emitters”. Alpha radiation is harmless outside the body, but extraordinarily damaging when inhaled, absorbed, or ingested.

Unlike most fission products, the heavier actinides typically have half-lives measured in tens of thousands of years, or even millions of years.

Most actinides are alpha-emitting radioactive materials

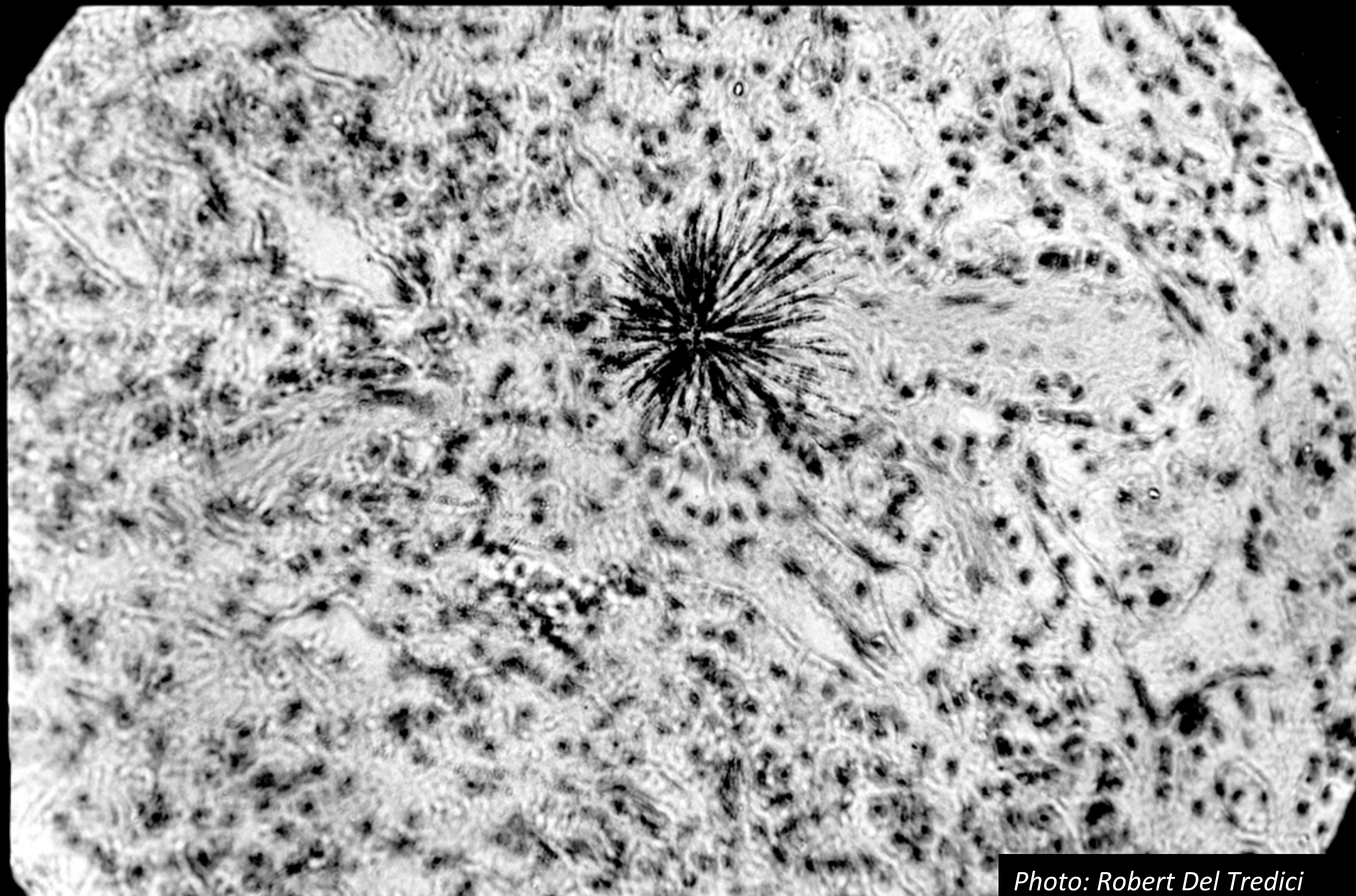
Alpha particles can be stopped by a sheet of paper.
Alpha emitters are harmless outside the body, but much more damaging than beta or gamma when ingested or inhaled.



Beta particles penetrate only part-way.
They can damage eyes or skin externally but the main danger is internal exposure.

Gamma rays are highly penetrating.
They give "whole body" radiation. Heavy shielding is often needed.

This photo shows a tiny speck of plutonium lodged in lung tissue.



The “spikes” are the tracks of alpha particles emitted over 48 hours.

The lung tissue of an experimental animal seen through a microscope over a period of 48 hours. At the centre of the "star" is a tiny radioactive particle of plutonium.

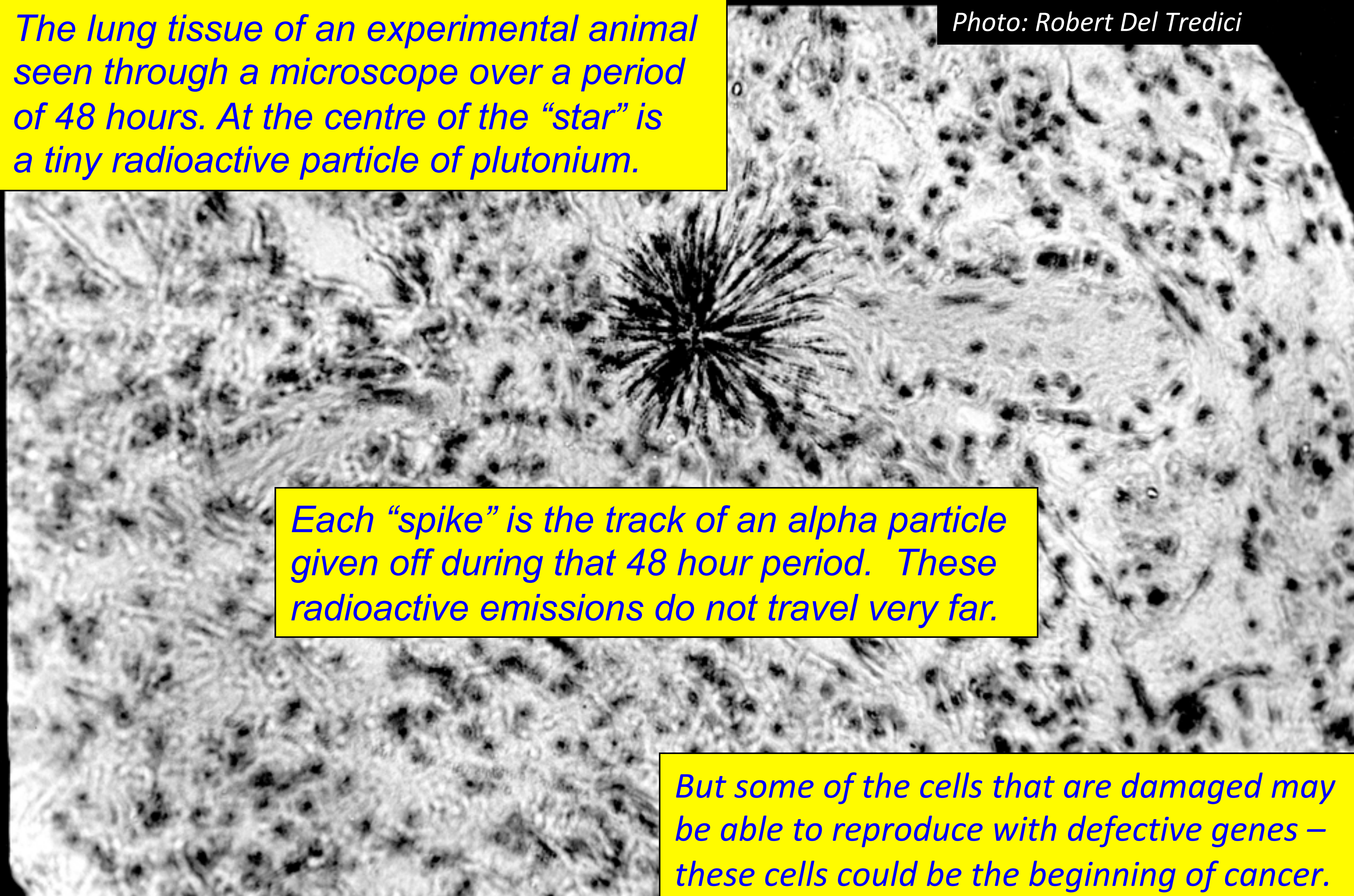


Photo: Robert Del Tredici

Each "spike" is the track of an alpha particle given off during that 48 hour period. These radioactive emissions do not travel very far.

But some of the cells that are damaged may be able to reproduce with defective genes – these cells could be the beginning of cancer.

radium, radon, polonium, thorium, plutonium, uranium – all alpha emitters.

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!

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

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

Isotopes	Becquerels per truckload	Becquerels per litre
Uranium-234	6.53 billion	28.1 million
Uranium-235	129 million	555 thousand
Uranium-236	84.2 million	362 thousand
Uranium-237	2.06 trillion	8.9 billion
Uranium-238	1.29 million	5.6 thousand
Neptunium-237	1.04 million	4.5 thousand
Plutonium-239	299 million	1.29 million
Plutonium-240	20.7 million	89 thousand
Strontium-90	10.1 trillion	43.5 billion
Yttrium-90	10.1 trillion	43.5 billion
Yttrium-91	2.42 million	10.4 thousand
Zirconium-95	10.8 million	46.5 thousand
Niobium-95	23.9 million	103 thousand
Ruthenium-106	255 billion	1.1 billion
Rhodium-106	255 billion	1.1 billion
Tellurium-127m	1.97 million	8.48 thousand
Tellurium-127	19.1 million	79 thousand
Iodine-129	2.94 million	12.7 thousand
Cesium-137	14.6 trillion	62.8 billion
Cerium-144	1.70 trillion	7.3 billion
Prometheum-147	7.25 trillion	31.3 billion

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!

Georgetown Reservoir : 530 million litres

providing drinking water for Washington DC

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	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.

Using cesium-137 content alone :

56 cubic centimetres of liquid
(1.9 fluid ounces) is enough

to ruin all the water in the
Georgetown reservoir

Canada's Nuclear Regulator

CNSC CCSN

Technical Assessment Report:
NAC-LWT Package Design for Transport of Highly Enriched Uranyl Nitrate Liquid

December 2014

The CNSC is giving out false information

(1) About the true composition of the Chalk River liquid,

(2) About the radiotoxicity of the Chalk River liquid.

(1) About the true composition of the Chalk River liquid:

CNSC calls it “uranyl nitrate liquid”.

This is false. Uranyl nitrate is only one chemical compound with only one radioactive element: Uranium.

The Chalk River liquid contains dozens of radionuclides and is at least 17,000 times more radioactive than uranium alone.

(2) About the radiotoxicity of the Chalk River liquid:

CNSC says *"The maximum leakage rate specified in the IAEA regulations was used, equivalent to a release of 0.033 percent of the contents."*

"In the unlikely event that an accident were to trigger intervention by government authorities at a drinking water supply plant, this would involve monitoring and possible temporary withdrawal of drinking water from public consumption . . . "

Message: "Just a minor inconvenience, folks!"

The CNSC says that a
release of 0.033 % of one
truckload would not be a major problem.

0.033 % of 232.4 litres is enough
to render 725 million litres of
water undrinkable.

That's 37 % more than the
Georgetown reservoir holds !

Part 4 : Alternatives

Solidification On Site

The Fissile Solution Storage Tank (FISST) has been full since 2003 (23,000 litres).

Highly radioactive liquid continues to be produced at Chalk River and is routinely solidified as it is produced.

Chalk River scientists have in recent years been solidifying other liquid waste stored in 20 other waste storage tanks on site.

Down-Blending On Site

Weapons-grade uranium can be eliminated by down-blending it with non-fissile uranium, turning it into low-enriched uranium that is not usable as a nuclear explosive material.

In 2016, Indonesia down-blended its entire stock of highly radioactive liquid waste with U.S. permission, without need for transportation.

In 2011 NRCan announced that the contents of the FISST tank would be down-blended on site.

The End

For more information:
ccnr@web.ca