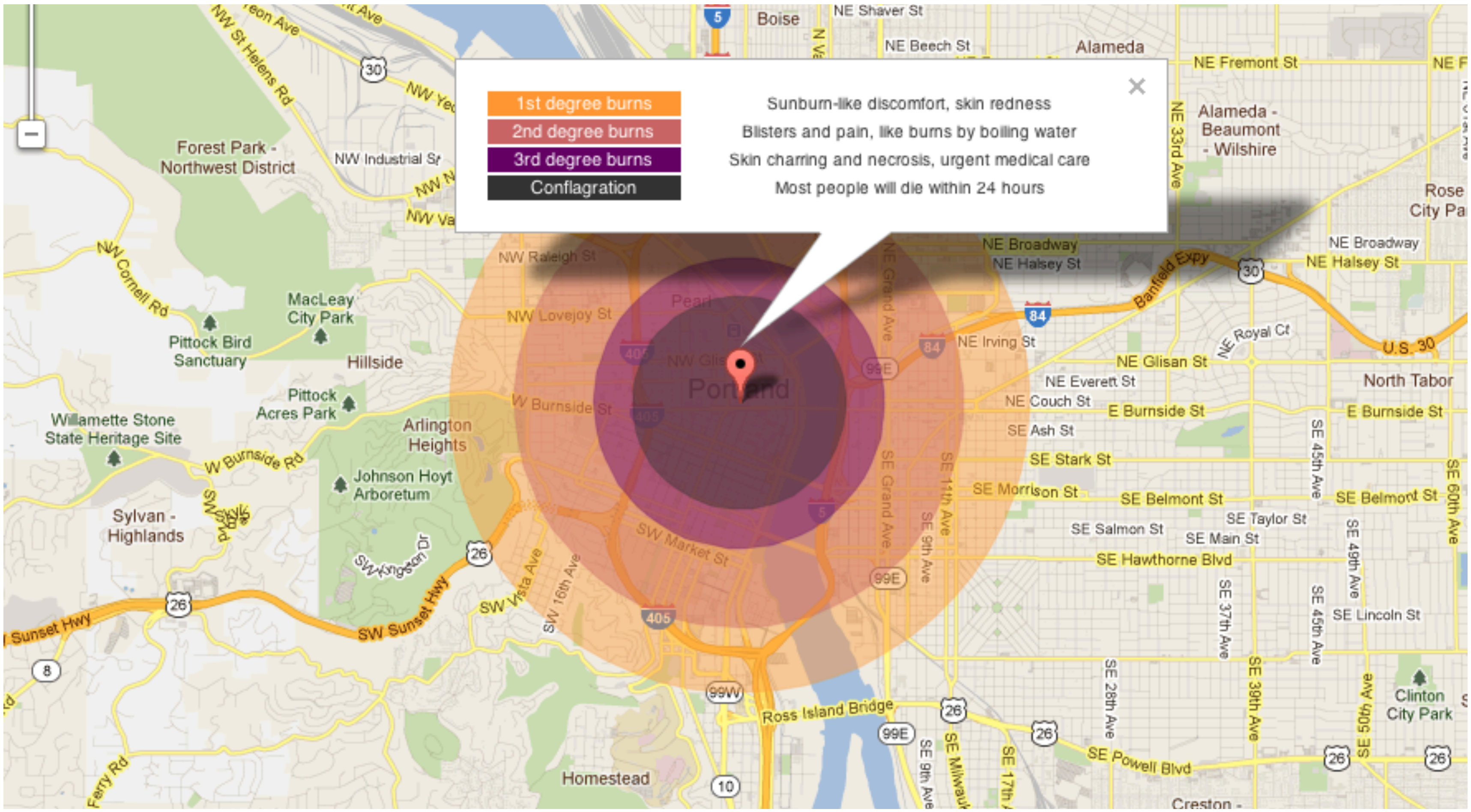
The Technology of Nuclear Energy and Weapons



I.Theory


Okay, so all I need nao...
...iz sum uranium
and a trigger
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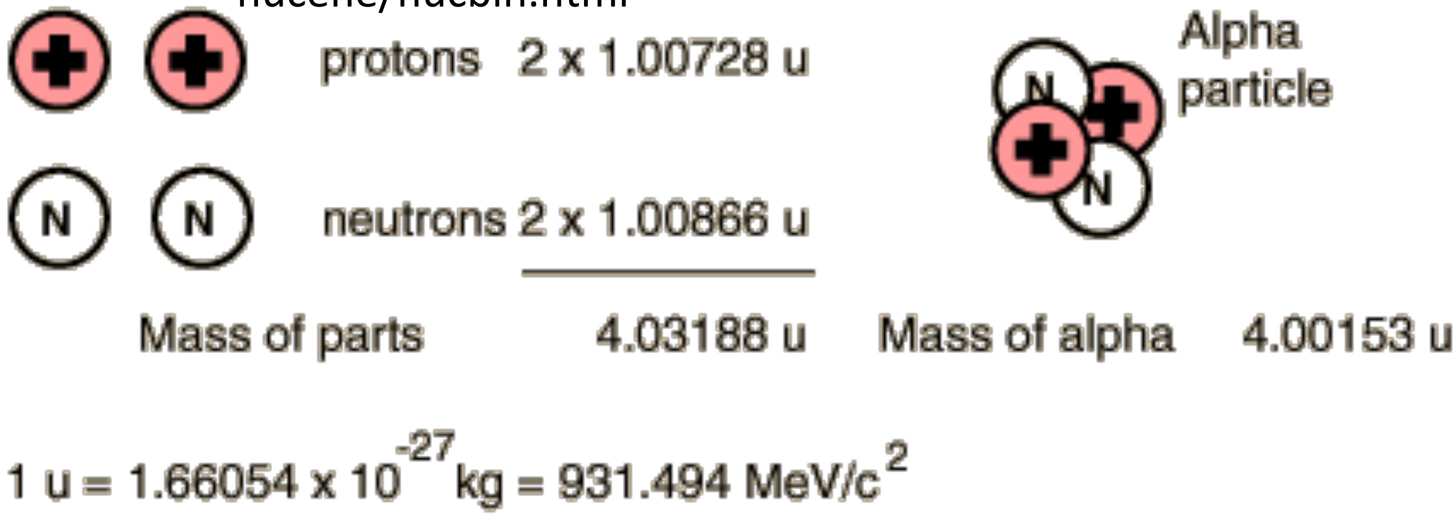
I.A.1. Nucleons and Atoms

Nuclear binding energy = Δmc^2

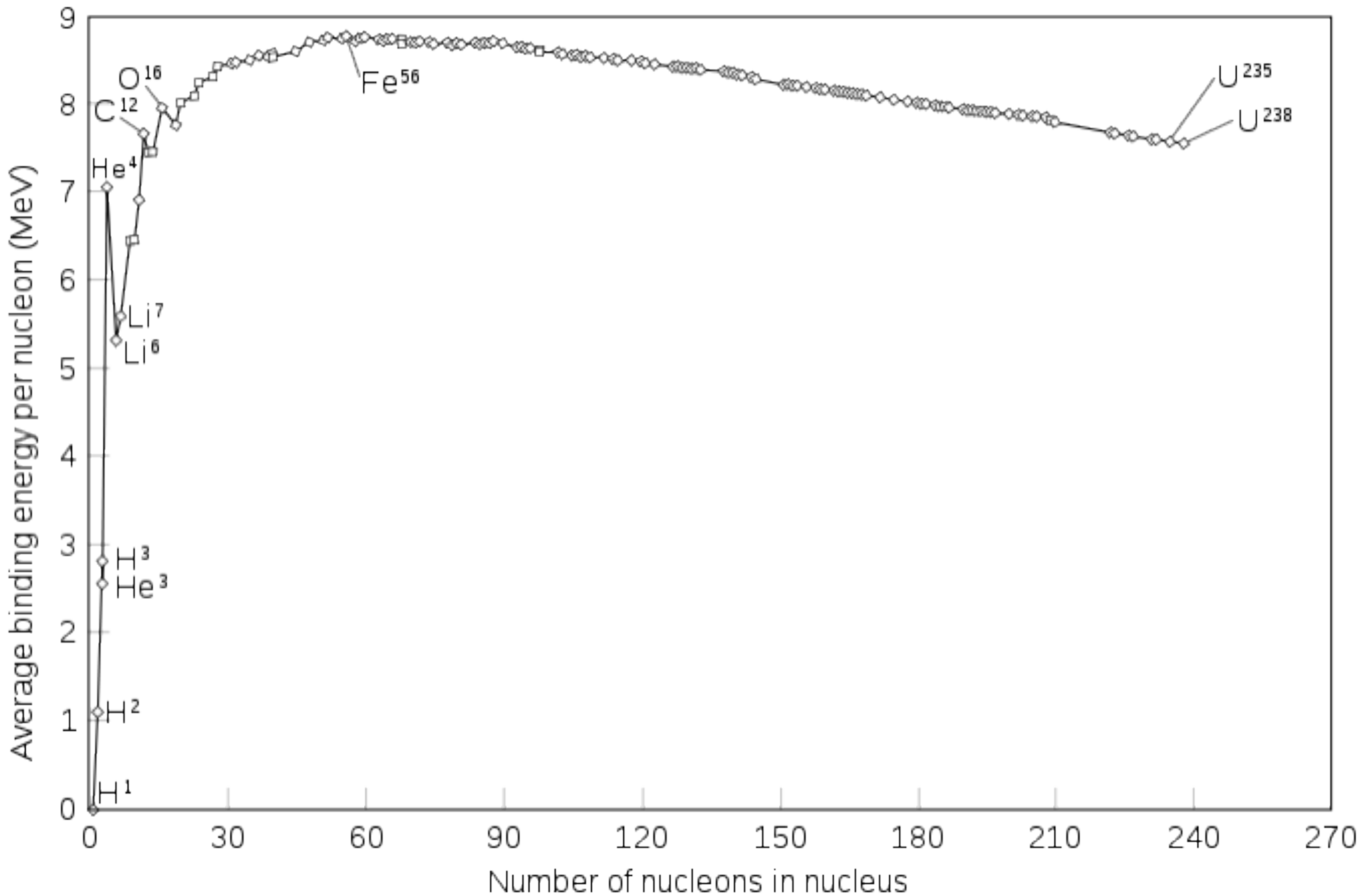
For the alpha particle $\Delta m = 0.0304$ u which gives a binding energy of 28.3 MeV.

http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/nucbin.html



- http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/nucbin.html

I.A.2.Curve of Binding Energy



- http://en.wikipedia.org/wiki/File:Binding_energy_curve_-_common_isotopes.svg

I.A.3.Isotopes (1)

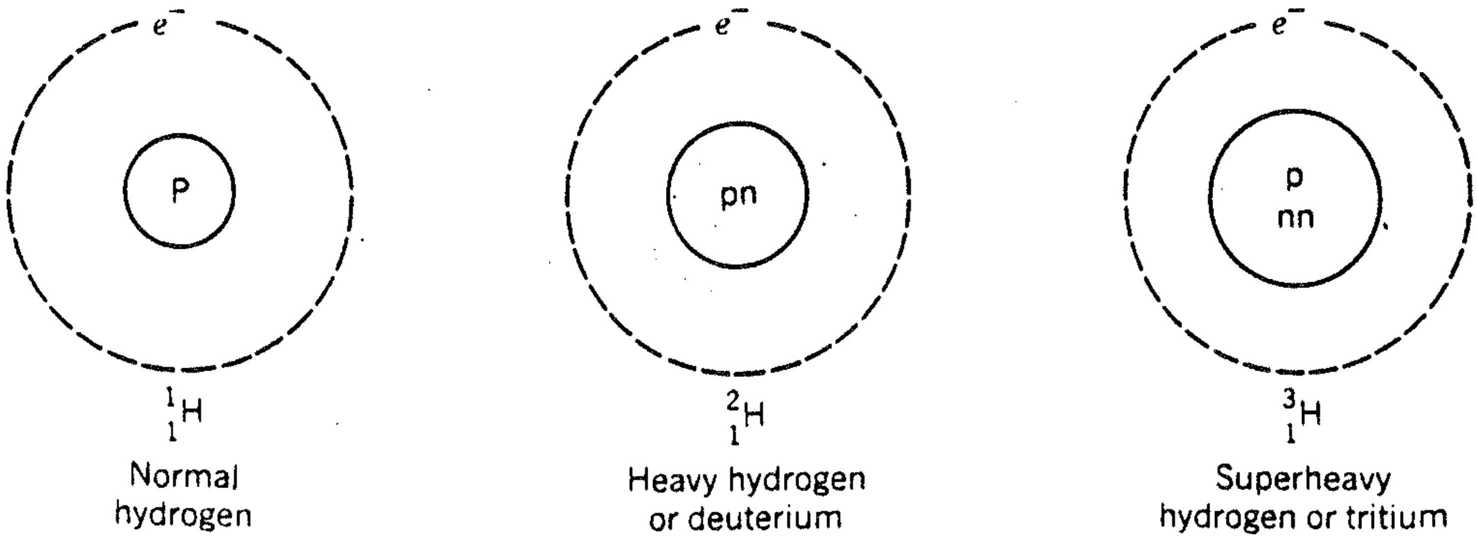


Figure 2.2 The isotopes of hydrogen are all characterized by $Z = 1$ since they each have one proton in the nucleus; their chemical characteristics are therefore essentially the same. However, they are characterized by different atomic masses $A = Z + N$ since they each have a different number N of neutrons in the nucleus; their nuclear properties are quite different.

- Dietrich Schroeer. *Science, technology, and the nuclear arms race*. Wiley, New York, NY, 1984. p.16

I.A.3.Isotopes (2)

Table 2.1 Isotopes relevant to the nuclear arms race, together with some of their more important properties.[a]

Isotope	Half-life	Emissions	Major Properties
^{2}H	Stable	None	Fuel for the H-bomb
^{3}H	12.3 years	β: 18.6 keV; γ: 550 keV	Fuel for the H-bomb
^{6}Li	Stable	None	Produce T by $^{6}Li + n \rightarrow {}^{3}H + {}^{4}He$
^{9}B	Stable	None	H-bomb tamper
^{14}C	5730 years	β: 156 kev	Produced from air by A-bombs
^{90}Sr	28 years	β: 546 keV; γ: 2.3 MeV	Fission product, bone seeker
^{131}I	8.05 days	β: 606 kev; γ: 364 keV	Fission product, thyroid seeker
^{137}Cs	30 years	β: 514 keV; γ: 662 keV	Fission product
^{233}U	165 kyrs	α: 5.3 MeV	Fissile material
^{235}U	710 Myrs	α: 4.4 MeV; γ: 185 keV	Fissile material, 0.7% of natural U
^{238}U	4500 Myrs	α: 4.2 MeV	"Contaminant" of ^{235}U
^{239}Pu	24.4 kyrs	α: 5.16 MeV	Fissile material
^{240}Pu	6580 yrs	α: 5.17 MeV	"Contaminant" of ^{239}Pu
^{242}Pu	380 kyrs	α: 4.9 MeV	"Contaminant" of ^{239}Pu

[a]The symbols kyrs and Myrs stand for 1000 and 1 million yr, respectively.

- Schroeer 1984, p.18

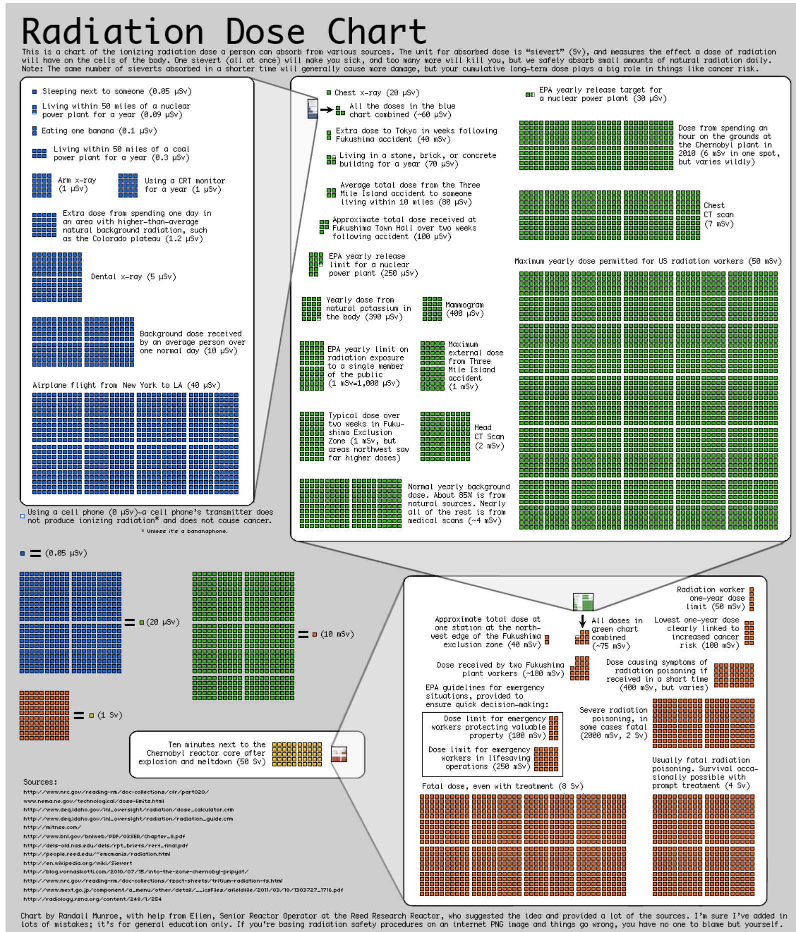
I.A.4.Radioactivity

Table 2.6 Symptoms of radiation sickness from observations made in Japan and on victims of nuclear accidents.
Based on Glasstone and Dolan, 1977, Table 12.108.

	Dose			
Symptoms	**150 rem**	**500 rem**	**600 rem**	**1000 rem**
Nausea and vomiting				
Incidence	Commonly	100%	100%	100%
Onset	A few hours	A few hours	A few hours	$\sim \frac{1}{2}$ hour
Duration	$\leqslant$ 1 day	1–2 days	$\leqslant$ 2 days	$\leqslant$ 1 day
Latent period (no symptoms)	2 weeks	2–3 weeks	$\leqslant$ 2 weeks	1 week
Final phase				
Duration	1 month	1 month	$\leqslant$ 1 month	1 week
Symptoms	Some loss of appetite; malaise; some depletion of leucocytes	Nausea; vomiting; malaise; diarrhea; hemorrhage under skin, from gums and intestines, and into organs; loss of hair; depletion of blood platelets; infection		
Survival	Essentially 100%	~50%	~10%	~0%

- Schroeer 1984, p.43

I.A.5.Radiation Dose



- http://xkcd.com/radiation/

1 Sievert = 1 J/kg = 100 rem

I.A.6.Half-lives

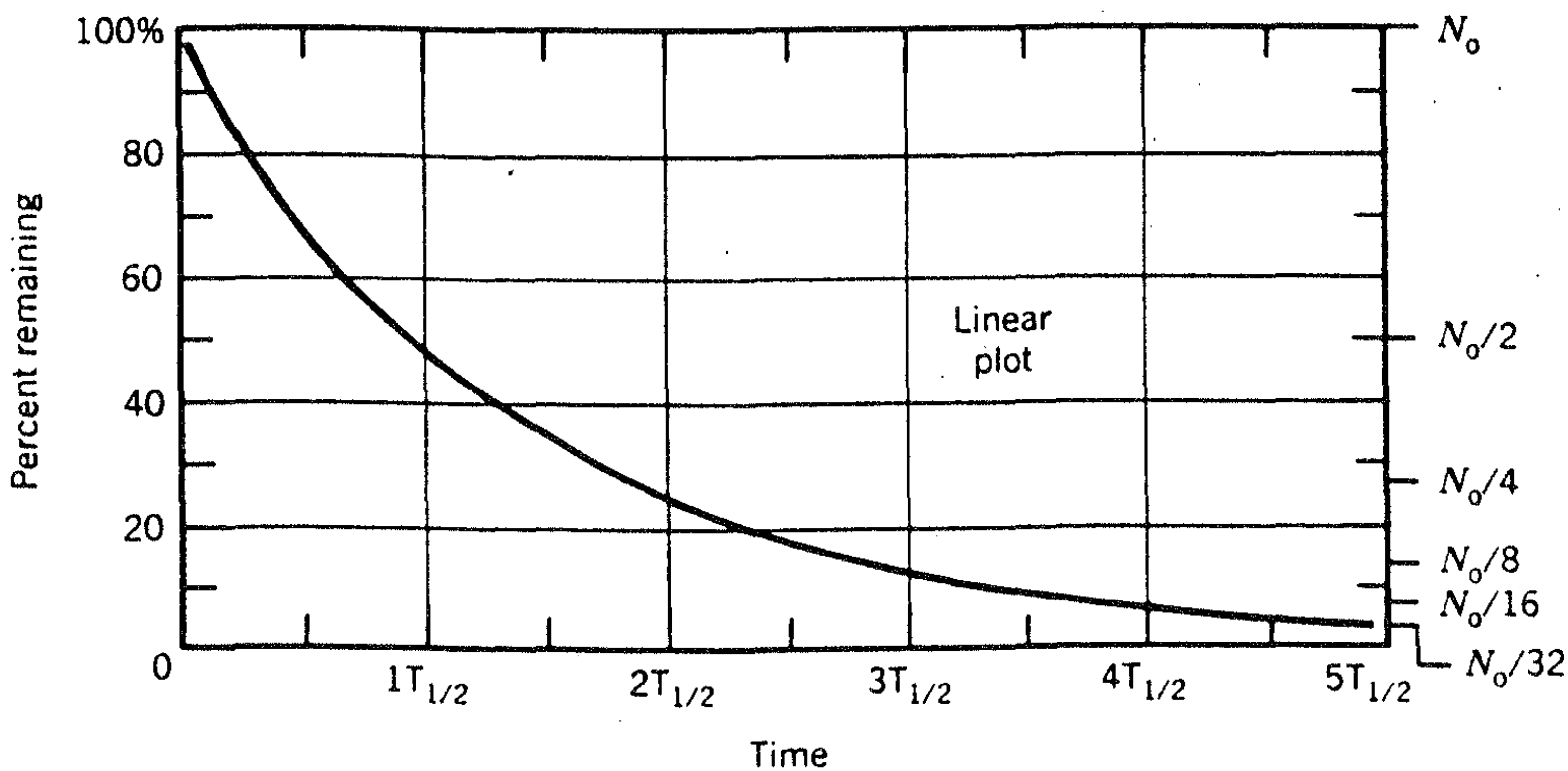
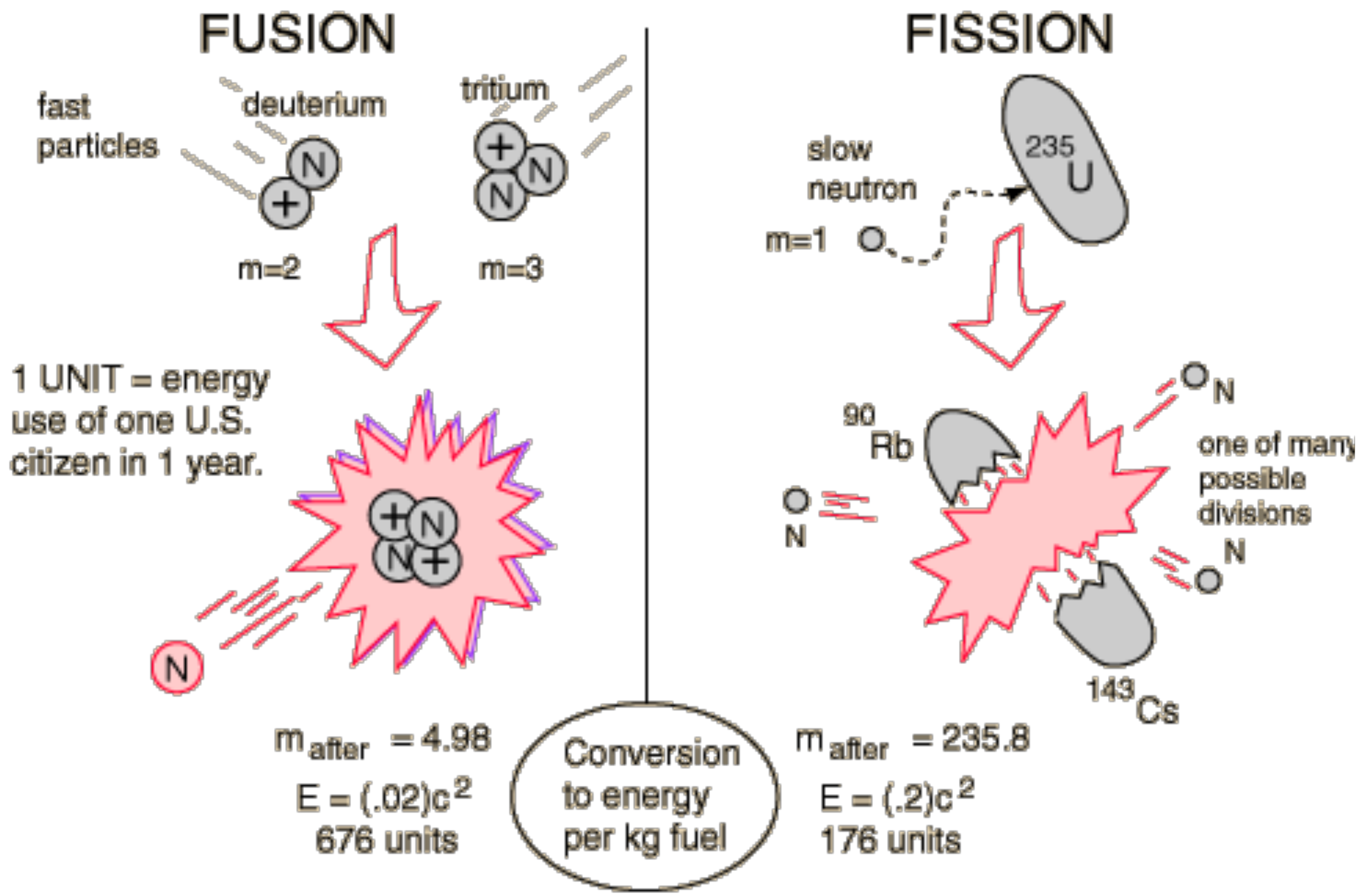


Figure 2.3 Plot of the exponential decay of an initial quantity N_0 of some parent isotope A with a half-life $T_{1/2}$.

- Schroeer 1984, p.17

I.B.1.Fission and Fusion



- http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/nucbin.html

I.B.2.Chemical v. Nuclear

Amount of substance required to produce enough energy for one US citizen in a year (5x10^11 J)

- Fusion: 0.0000016 tons
- Fission: 0.0000063 tons
- Gasoline: 2800 gallons (8.6 tons)
- Natural Gas: 500,000 cubic feet (11.1 tons)
- Coal: 20 tons

- http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/eneein.html#c2

I.B.3.Chain Reactions

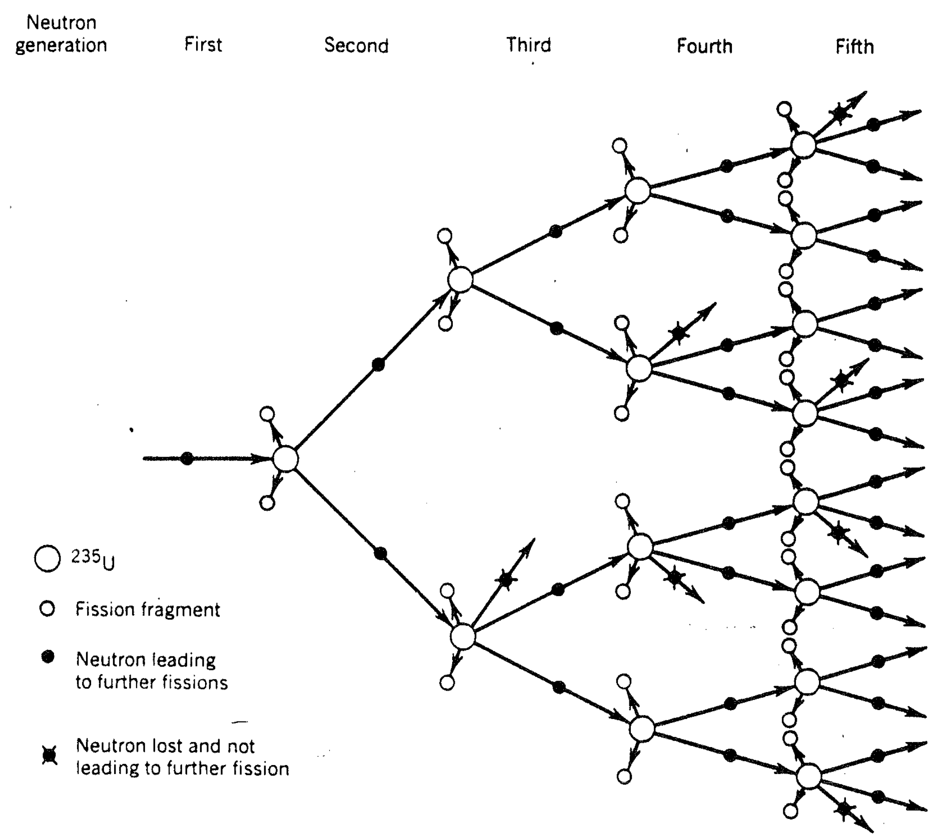


Figure 2.4 Sketch of a chain reaction in ^{235}U assuming an average of 2.5 neutrons released per fission event and a loss on the average of 1 out of 5 neutrons through absorption or escape from the fissioning mass.

- Schroeer 1984, p.22

I.B.4.Critical mass

Table 2.3 The critical mass for fission bombs utilizing ^{239}Pu or ^{235}U of various enrichment levels.

The bomb material may be made of metal or oxide, and various surrounding neutron reflectors (tampers) may be used. Adapted from A. de Volpi, 1979, p. 70 and pp. 203–211.

	Tamper		
Bomb Material	**None**	**10 cm of Uranium**	**10 cm of Beryllium**
^{239}Pu, α phase			
(0% ^{240}Pu)	10 kg	4.5 kg	4 kg
(20% ^{240}Pu)		5.4 kg	
(50% ^{240}Pu)		8.7 kg	
^{239}Pu, δ phase	16 kg	7.0 kg	
$^{239}PuO_2$	26 kg		
^{235}U (0% ^{238}U)	47 kg	16 kg	14 kg
^{235}U (50% ^{238}U)	68 kg		25 kg
^{235}U (80% ^{238}U)	160 kg		65 kg
$^{235}UO_2$ (0% ^{238}U)	100 kg		
^{233}U		5.5 kg	

- Schroeer 1984, p.31

I.B.4.Nuclear Power Plants

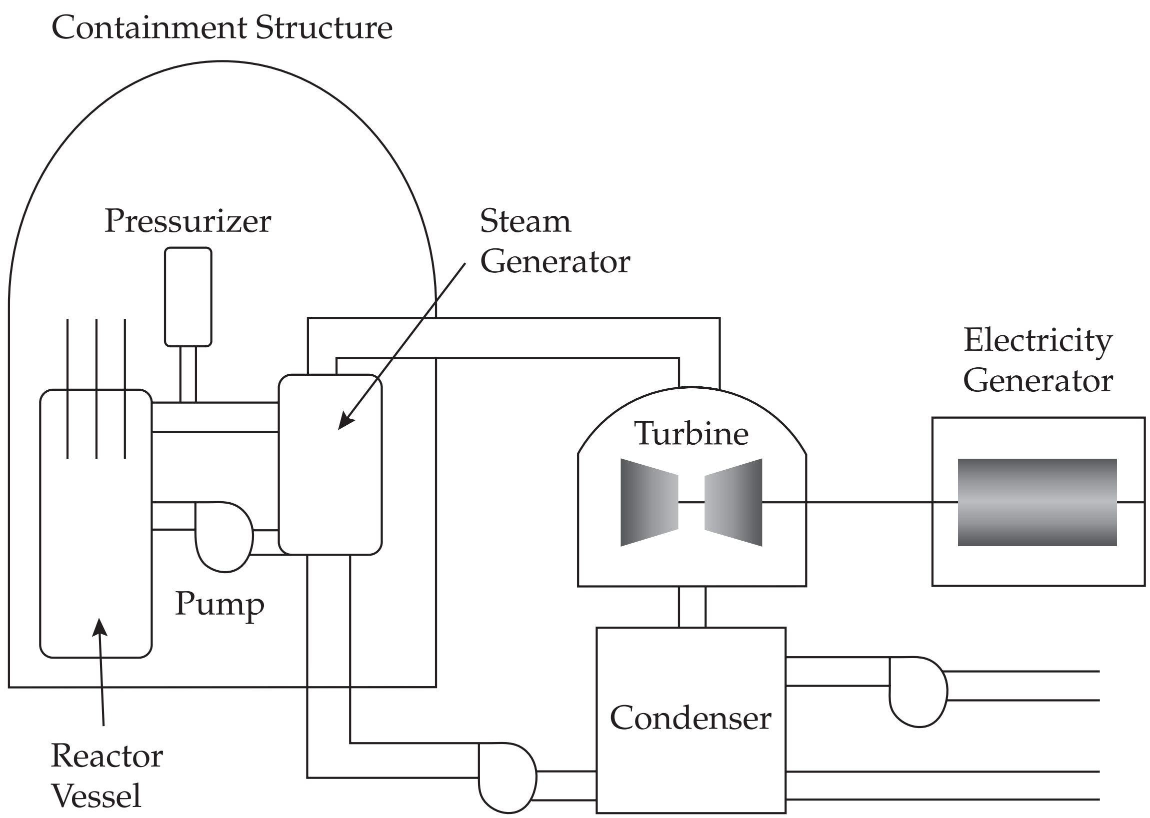


FIGURE 1.2: Schematic of a power plant including a pressurized-water reactor.

- Ferguson 2011, p.46

II.Practice


INCOMPETENCE
Just because you have the tools doesn't mean you know how to use them.
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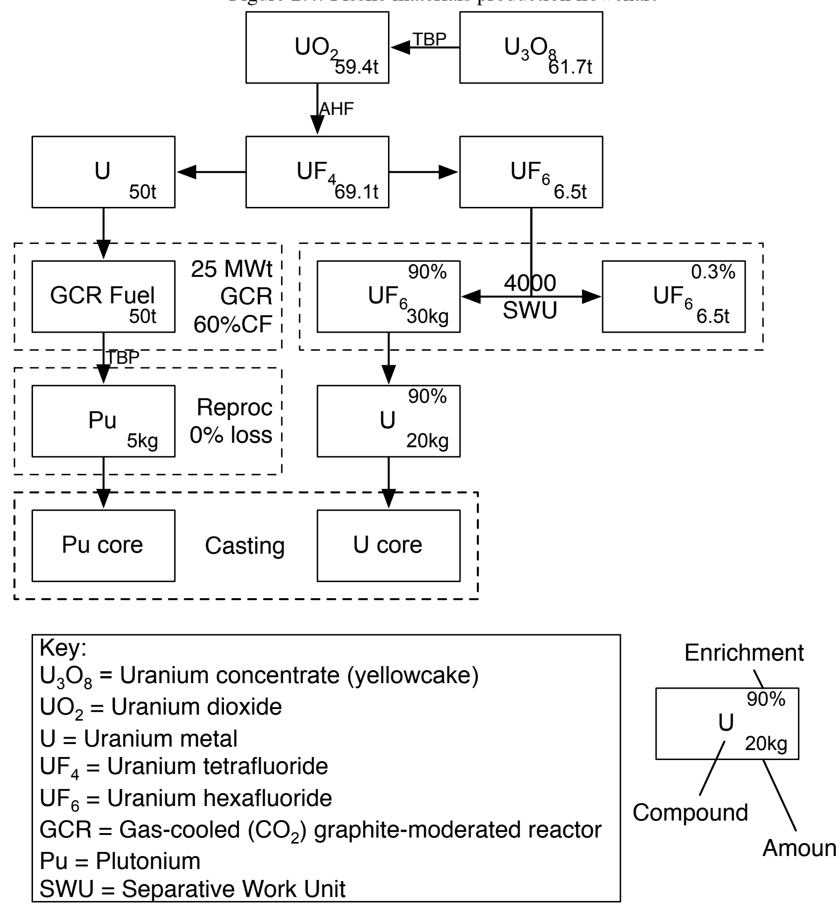
II.A.Fissile Materials Production

Table 2.3: Fissile materials production methods

			Plutonium[a]		
	Reactor Type (#)	Start Date	Net Total tons (2004)	Weapons (4 kg Pu)	End Date
SA	LWGR(9)	1944	99.5	24875	1987
	HWR(5)	1953			1988
ıssia	LWGR(13)	1948	145	36250	1994
K	GCR(8)	1951	7.6	1900	1995
ance	GCR(3)	1956	5	1250	1994
	HWR(2)	1967			?
dia[b]	HWR(2)	1960	0.38	95	N/A
rael	HWR(1)	1963	0.58	145	N/A
ıina	LWGR(2)	1966	4.8	1200	1991
ıkistan	HWR(1)	1998	0.04	10	N/A
			Highly Enriched Uranium		
	Separation Method	Start Date	Net Total tons (2004)	Weapons (15 kg WGU)	
SA	GD	1944	480	24000	1964
	EMIS	1945			1947
ıssia	GD	1945	710	35500	1988
	EMIS	1945			?
	Cent	1946			1987
K	GD	1954	16	800	1962
ıina	GD	1964	20	1000	1987
ance	GD	1967	25	1250	1996
ıkistan	Cent	1986	1.1	55	N/A
Africa[c]	Aero	1979	0.5	25	1989

Figure 2.4: Fissile materials production flowchart



- Montgomery 2005

II.B.1.Gun-type

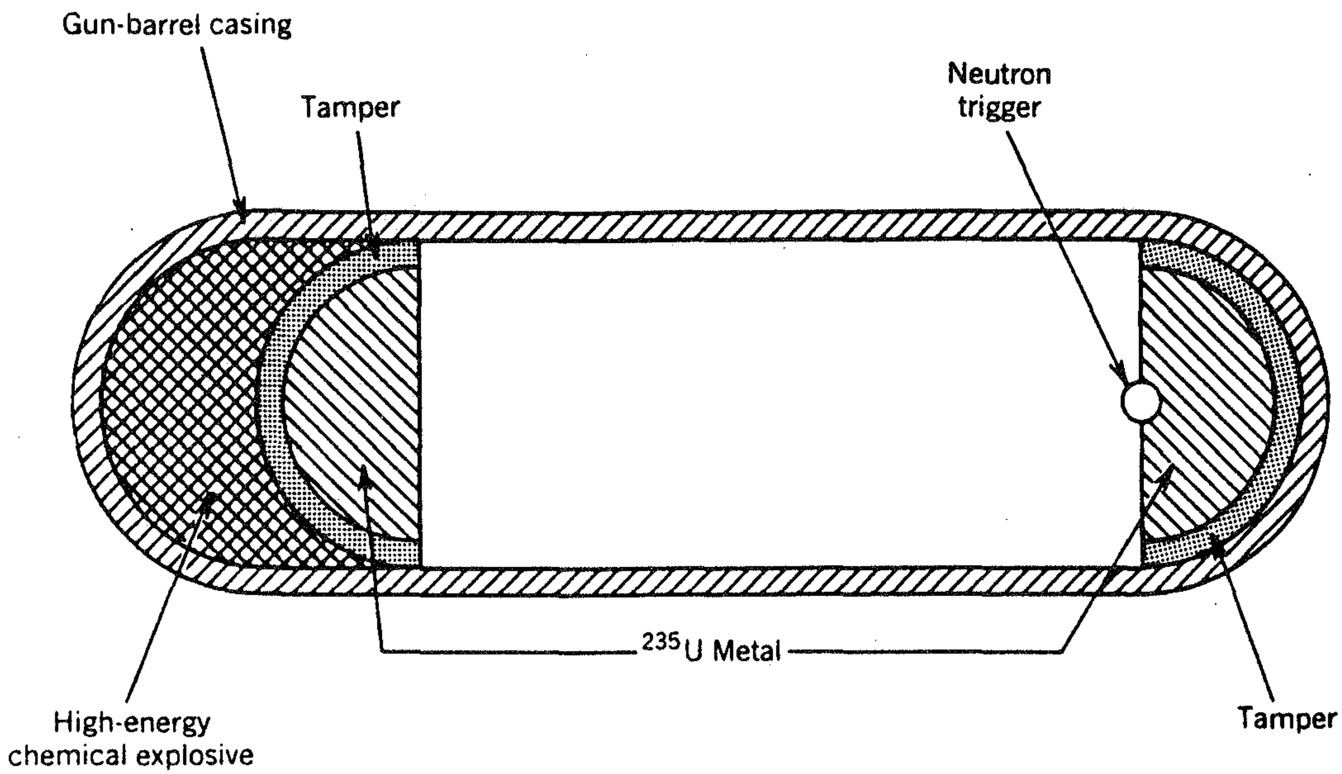


Figure 2.8 Gun-barrel design for a nuclear fission device using ^{235}U as the fissile material. The chemical explosive drives two subcritical masses together, creating a supercritical mass that can undergo a rapidly growing chain reaction.

- Schrooer 1984, p.32

II.B.2.Implosion

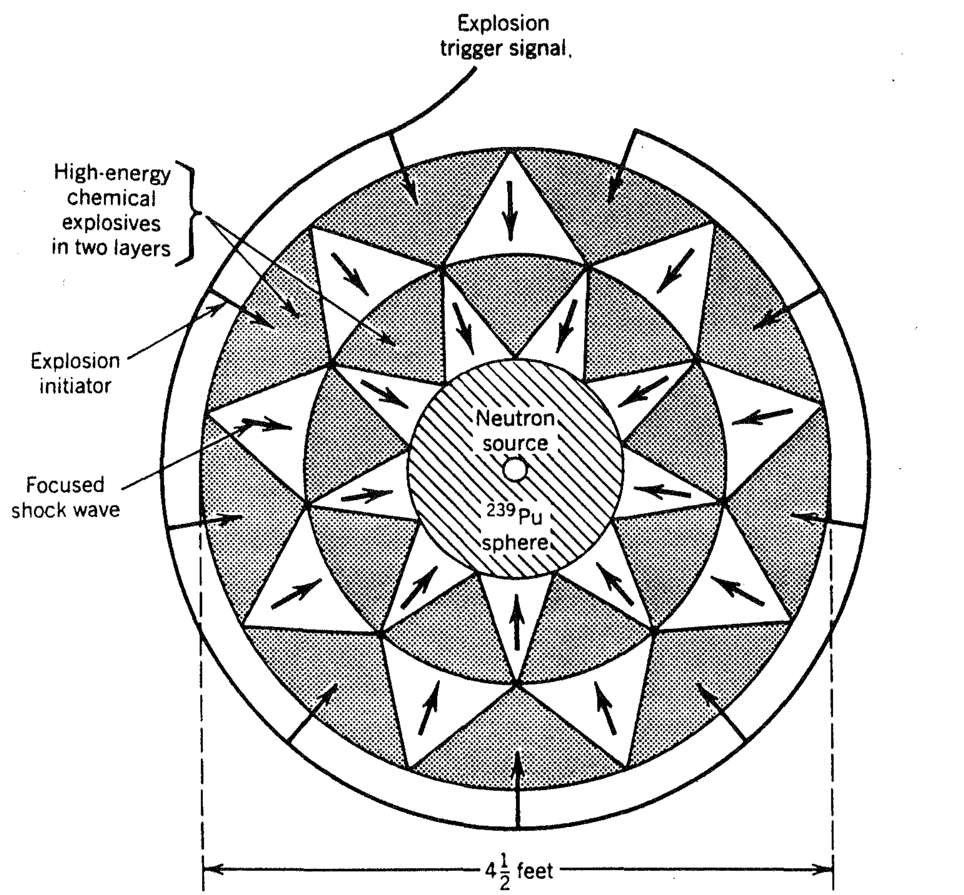
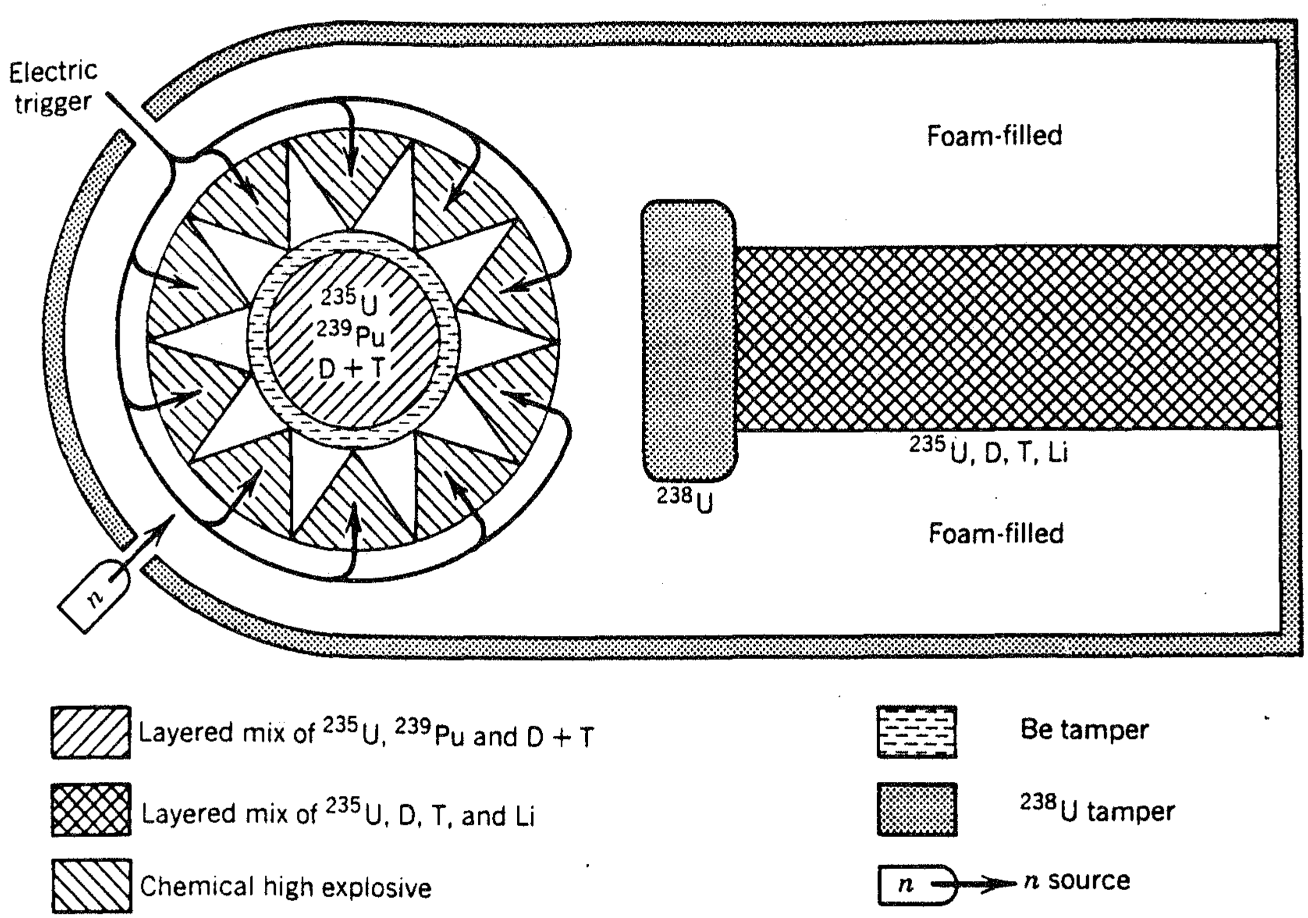


Figure 2.9 Design sketch of the first ^{239}Pu implosion nuclear bomb (not drawn to scale).

- Schroeer 1984, p.33

II.B.3.Thermonuclear



- Schroeer 1984, p.63

III.A.Rules of Thumb

- Energy and Distance
  - Cube root of the yield
  - Energy: 50% blast, 35% thermal, 5% prompt radiation, 10% FIPS
- Things that Will Kill You
  - Blast (5 psi from things falling on you)
  - Thermal (3^{rd} degree burns)
  - Radiation (500 rem)
  - Fallout (Sr, I, Pu?)

III.B.What Will Kill You? (Fig. 2.19, p. 47)

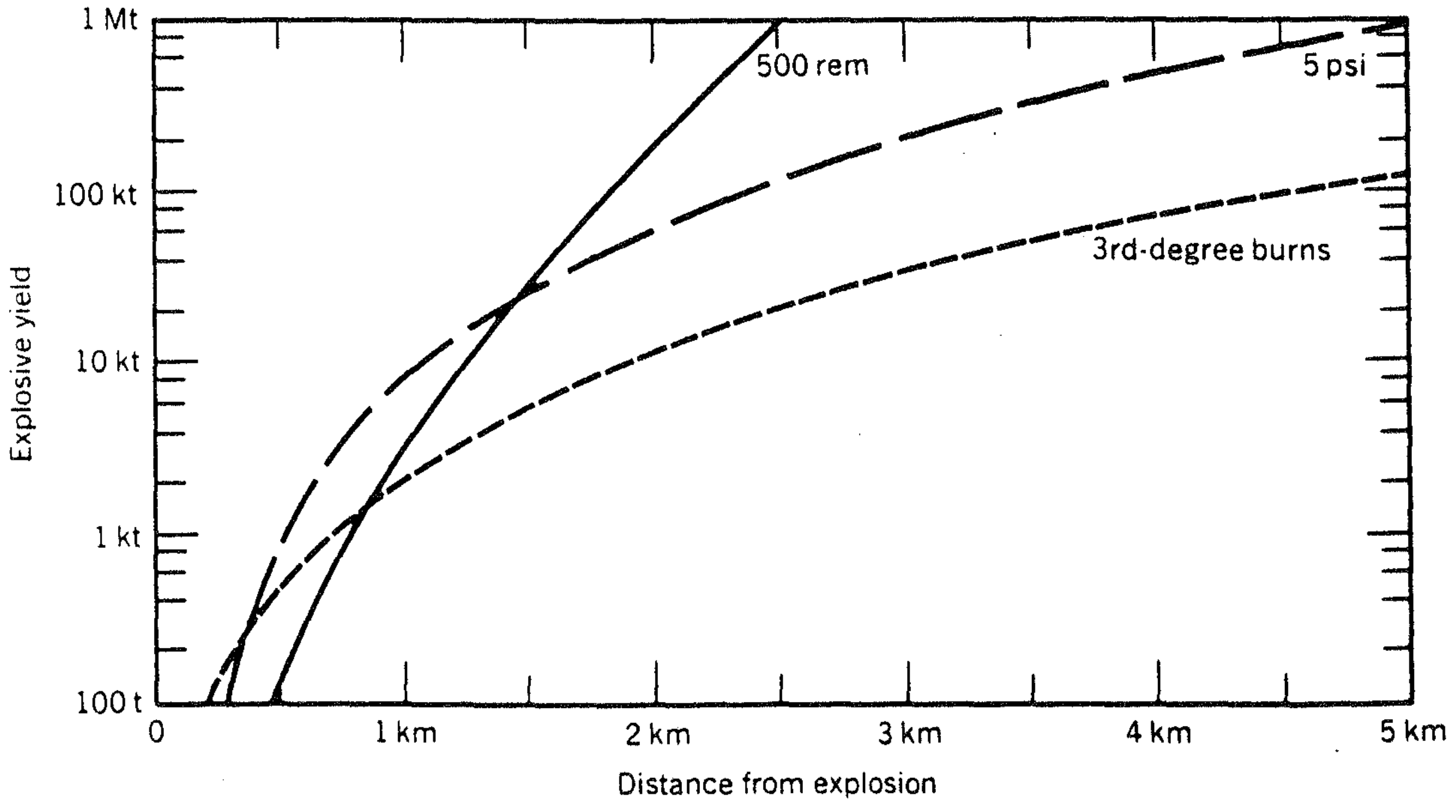
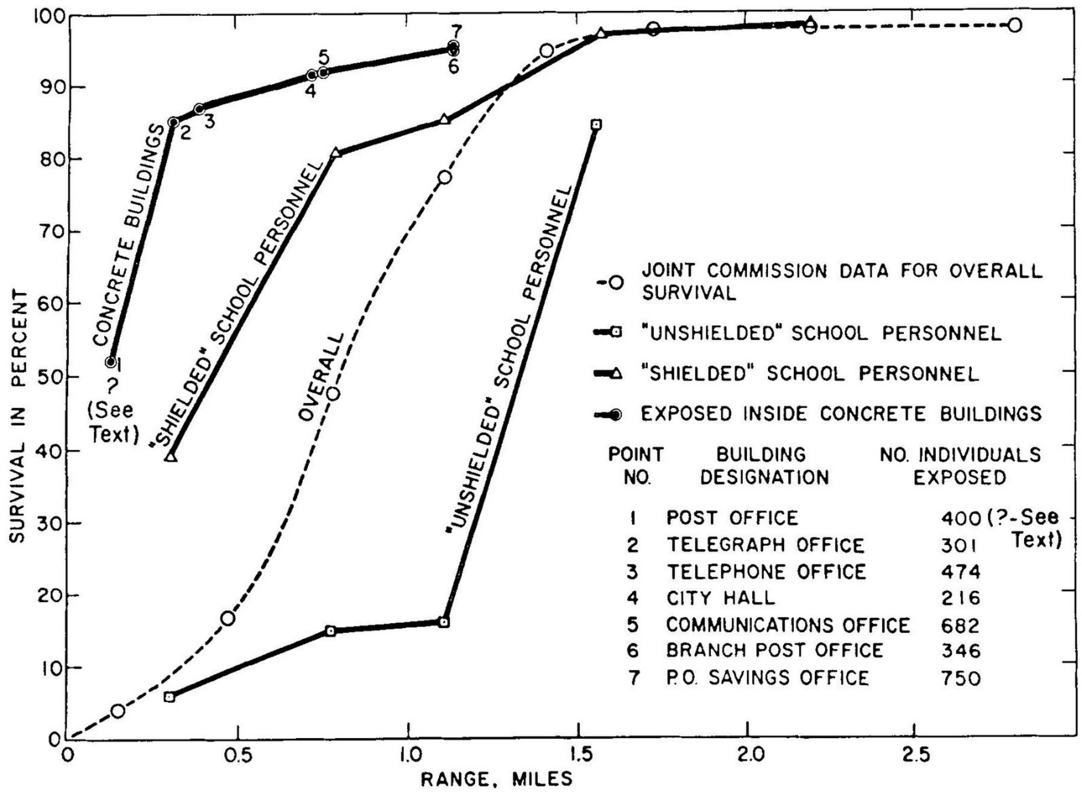


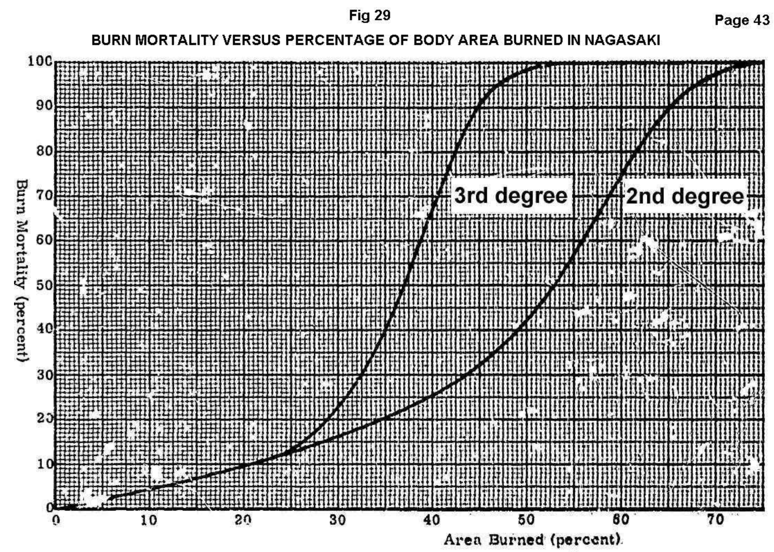
Figure 2.19 Damage radii for various effects from nuclear weapons, based on Tables 2.4 and 2.5.

- Schroeer 1984, p.47

III.C.Hiroshima



Percentage of survivors as a function of range from Ground Zero (Hiroshima). (Ref. Joint Commission Report, Vol. VI, Document NP-3041.)



Data from Davis, Baker, and Summers, "Analysis of Japanese Nuclear Casualty Data", Reports DC-FR-1045 and 1054, Dikewood Corp., Albuquerque

FIFTY-PER CENT SURVIVAL CONDITIONS FOR HIROSHIMA

LOCATION	HORIZONTAL RANGE mi	MAX OVER-PRESSURE psi	THERMAL RADIATION cal/cm^2
CONCRETE			
BASEMENT	.10	25.6	80
LOWER FLOORS	.08	26.4	83
MIDDLE FLOORS	.20	19.8	67
UPPER FLOORS	.23	18.0	63

Davis, Baker, and Summers, "Analysis of Japanese Nuclear Casualty Data", Reports DC-FR-1045 and 1054 Dikewood Corp., Albuquerque, N.M.