Fission Weapons

Diffusion Equations run amuck

By Scott Stafford

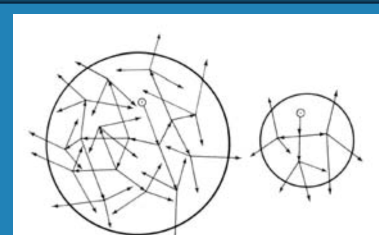
The Desired Result

- The process of fissioning an atom produces, on average, 170 MeV per fission event. This is approximately 10^8 times the heat of reaction per atom in an ordinary combustion process.
- The desire was to harness this energy into an explosive effect.
- In a mass of 1 kg of U-235 with 2.58×10^{24} nuclei it would require n=81 generations for all U-235 atoms to fission(assuming no loss to the surface). Since each fission occurs in about 10^{-8} seconds, the 81 generations would occur in 0.81 microseconds.

The Desired Result

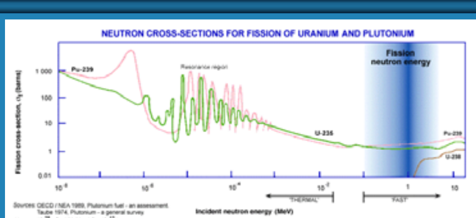
- During this entire fissioning process, the energy released is making the material very hot and developing tremendous pressure…this is the explosive result. If the reaction were to proceed at 10% efficiency the Uranium would be initially heated to approx. 10^{10} °C in less than a millionth of a second. The pressure rises similarly.
- But there are problems….

The Fissionable Sphere



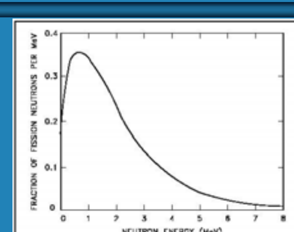
We lose neutrons to the surface

Fission Cross Section



We are interested in Fast Fission processes (approx. 1 MeV neutrons)

Neutron Spectrum



The bulk of the fission neutrons are at 1 MeV or higher

Diffusion Equation

Neutrons Produced per fission event

Neutrons lost to next fission event

$$\frac{dN}{dt} = -div(j) + \frac{\nu - 1}{\tau} N \qquad j = -DgradN$$

Mean time between fissions

and…..

$$\frac{dN}{dt} = D\Delta N + \frac{(\nu - 1)}{\tau} N$$

When all is said and calculated…..

- We find that R_c= 9.26 cm for U-235 and

$$M_C \propto \frac{1}{\rho^2} \frac{1}{[\sigma_f \sigma_t (\nu - 1)]^{3/2}}$$

- Thus M_c(Critical Mass) is proportional to $1/\rho^2$
- But again..there are more problems

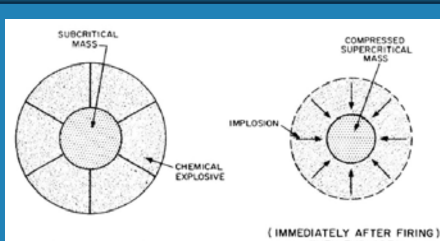
The Expansion…

- As the initial fission reaction proceeds, the temperature and pressure in the sphere is increasing substantially.
- This causes the material in the sphere to expand, decreasing the density, and thus increasing the critical mass required.
- This will stop the reaction as it is proceeding and reduce the total energy released.

The Tamper…

- If we surround the sphere with a dense shell, there will be reflection of neutrons that would otherwise escape
- Also, the tendency of the sphere to expand during the fissioning process would be reduced
- But it is not enough….

The Implosion…



The Implosion…

- A spherical shock wave converges on the sphere and compresses it
- Since the critical mass is α $1/\rho^2$ an increase in density of a factor of 2 results in a reduction of the critical mass necessary by a factor of 4

The Implosion....

- This will cause the previous sub-critical mass to go “prompt” super critical.
- Also, the implosion helps initially reduce the sphere’s tendency to expand near the final neutron generations.
- Thus the efficiency of the energy released is increased (≈20%)