Greenhouse George D+T Fusion Historical Experiment

Ara Barsamian
Nuclear Non-Proliferation Institute
www.nuclearnonproliferation.org

Test Description and Objectives

This paper commemorates the 60th anniversary of the first man-made thermonuclear fusion burn experiment on earth in 1951.

Greenhouse George test explosion was a thermonuclear physics experiment to demonstrate that D+T fusion burn does occur when subjected to intense heat. Until that time, the only demonstration of D+T fusion reaction was done with particle accelerators, shooting deuterons into a target impregnated with Tritium (or vice-versa).

The test explosive device, named the CYLINDER[1], consisted of a highly enriched uranium (HEU) core with an ordinary U238 tamper and a cylindrical HE implosion system. This device used a GE miniature betatron as an external neutron system (ENS) initiator to begin the fission chain reaction.

The George device[2] was a disk about 240 cm across and 60cm thick perforated by an axial hole. The HEU cylinder, when imploded, it became supercritical, and the ENS provided the initiating neutrons, producing a fission yield of about 200 kilotons (produced by fission of about 12 kg of U235 at 17kt/kg, and assuming 25% efficiency, the HEU cylinder weight was about 48kg).

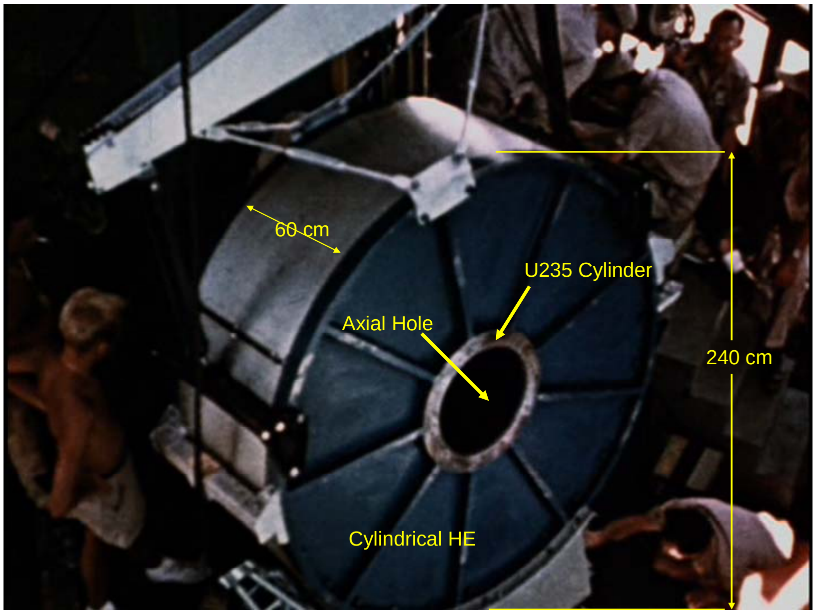

Fig. 1 Back view of Cylinder Device[2]

The axial hole, compressed to a narrow channel by the implosion, conducted the thermal x-rays radiation to a small (~15 cm) beryllium oxide sphere (Beryllium is transparent to x-rays) containing a 50:50 mixture of liquid deuterium - tritium. The radiation ducting occurs because the U235 fission explosive axial exit hole and the BeO sphere are enclosed together in a common lead shield to "contain" the thermal x-rays, a sort of primitive "hohlraum" radiation case.

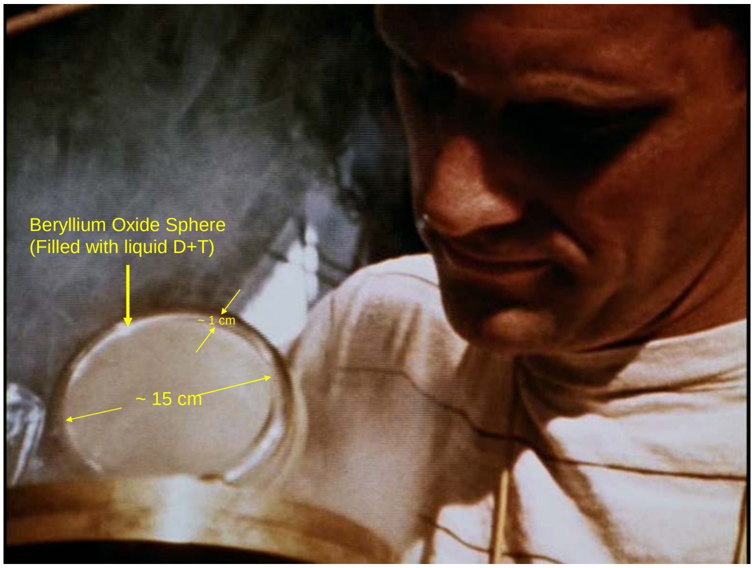

Fig. 2 The BeO Spherical Container with Liquid D+T Mixture[2]

The thermal x-rays radiation simultaneously heats the BeO sphere fuel chamber walls (due to the opacity of Oxygen in BeO) and the D+T mixture to fusion temperatures, and the pressure in the BeO wall causes it to partially explode and partially implode (using so-called "exploding pusher" concept used in inertial confinement fusion experiments[3]) and compress "mildly" the D+T fusion fuel, accelerating its combustion. The thermal radiation arrives ahead of the shock front of the fission explosion, allowing time for a

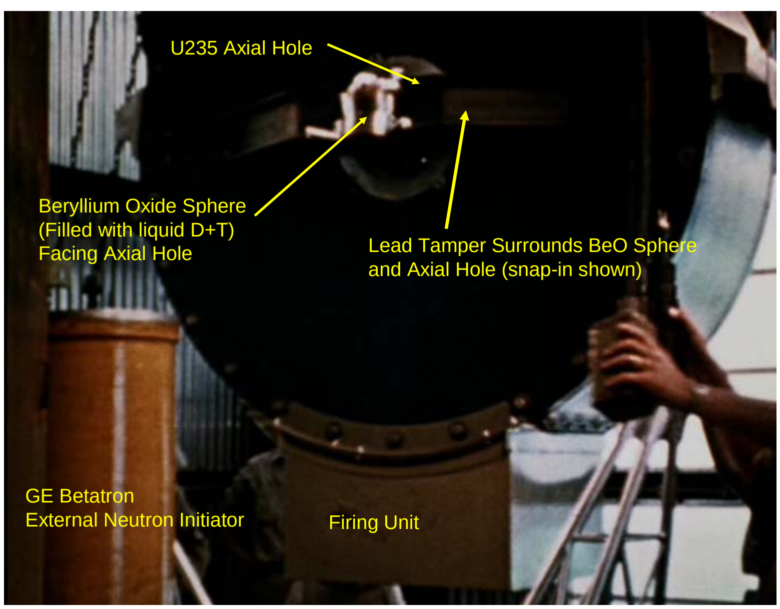

Fig. 3 Front View of Cylinder Device and Equipment Placement[2]

fusion reaction to occur before being engulfed by the expanding fission fireball. The yield of the fusion reaction was estimated at ~25kt, negligible compared to the 200kt fission yield.

The success of the fusion burn was observed by detecting the presence and intensity of characteristic "tell-tale" fingerprint of 14 MeV neutrons from D+T fusion burn plasma.

Contrary to various misleading information, this **WAS NOT** a preliminary test of the Teller-Ulam concept, and neither of the radiation-driven ablation concept. The exploding pusher compression is mild (factor of 10 to 20) vs. ablative compression factor 100 to 1000...

Comments on Confusion About Radiation Implosion Driven Compression Concepts

There seems to be a lot of confusion among the historians and writers of H-bomb history, mostly because they lack a scientific background, and until recently (1979 Progressive case) it was one of the top secrets of the nuclear weapons establishment, so people steered clear of "born secret" controversy. Now with the declassification of indirect drive Inertial Confinement Fusion (ICF), these concepts are widely published.

There are three radically different radiation implosion driven compression mechanisms:

1. Exploding pusher type[4], where the radiation simultaneously heats BOTH the fuel capsule shell and the fuel itself. From a fusion point of view, this is very inefficient because we obviously want to maximize fuel compression to increase the fusion rate, and this maximum compression of fusion fuel occurs when the fuel is cold, not when hot.

This concept was the basis of the "Fuchs-von Neumann" Super ignition patent, and also used in Sakharov's Sloika, where it was called ionization compression, or Sakharization. When you get the fuel capsule (wall+contents) into thermal equilibrium, the denser capsule wall acts like a high explosive, trying also to equalize the wall material and fuel ion density, thus compressing the D+T somewhat in the ratio of ionized wall density to fuel density, so it is not a great amount of compression, approximately by a factor of about 10 to 20.

2. Ablative Pusher Compression[5], where the radiation ablates the shell surrounding the fuel. Using Newton's 3rd law and the "rocket" equation, one can estimate the pressure generated by ablation, to be in hundred or thousands of megabars, depending on the ablator material (the preferred ablator for weapons is Beryllium which produces the highest ablation pressure) and thermal x-ray intensity. Additional "tricks" like isentropic compression by profiling the radiation pulse or the ablator composition easily doubles the fuel compression.

The fusion fuel stays cold and gets highly compressed because there is a shield around it, like a Uranium or Plutonium pusher/tamper impervious to x-rays.

3. Heated Matter Compression[6], where the radiation heats a channel filler material (e.g. Beryllium Oxide filled foam) converting it into an energized plasma that drives a strong shock in the pusher/tamper shell. According to Garwin[7] (the designer of Mike H-bomb experiment), the pressures generated inside the radiation case by heated matter that squeezes the fusion secondary has an energy density of roughly 1.4TJ/L, or about 1400 megabars. This was the compression mechanism used in Mike.

As one can imagine, there are a number of other "variations-on-a-theme" combining 1) , 2), and 3) to various degrees, but they are derivatives of the above fundamental concepts.

References

[1 Sublette, C. Nuclear Weapons Archive, "Operation Greenhouse George Test", URL: http://nuclearweaponarchive.org/Usa/Tests/Grnhouse.html
[2] Photo credits: US DOE and Peter Kuran, "Trinity and Beyond: The Atomic Bomb Movie", DVD, Visual Concept Entertainment, 1999
[3] York, H., "Transcript of Interview, AIP Oral History Program", American Institute of Physics , Aug. 24, 2008
[4] Giovanielli et al, LAMS-7218-MS, "Simple Model For Exploding Pusher Targets", May 1978
[5] Nuckolls, JH, "Contributions to the Genesis and Progress of ICF", in "Inertial Confinement Nuclear Fusion, a Historical Approach by its Pioneers", G. Velarde, editor, pp.1-48, Foxwell and Davies, Ltd, 2007
[6] Shipps, PR et al, " Nuclear Pulse Space Vehicle Study", Report GA-5009, Vol. III, pp.9-12, Sept 19, 1964
[7] Garwin, RL, " Maintaining Nuclear Weapons Safe and Reliable Under a CTBT", Special session on the Comprehensive Test Ban Treaty at the American Geophysical Union Spring Meeting, pp.6, May 31, 2000