The following 7 pages of information and data was gathered and assembled by H. Newton.
Data within this PDF is a reasonable starting place for the 50K V/M estimation/determination.

Gas boosting in modern nuclear weapons

http://nuclearweaponarchive.org/Nwfaq/Nfaq12.html

http://nuclearweaponarchive.org/Nwfaq/Nfaq4-3.html

In a fission bomb, the fissile fuel is "assembled" quickly by a uniform spherical implosion created with conventional explosives, producing a supercritical mass. In this state, many of the neutrons released by the fissioning of a nucleus will induce fission of other nuclei in the fuel mass, also releasing additional neutrons, leading to a chain reaction. This reaction consumes at most 20% of the fuel before the bomb blows itself apart, or possibly much less if conditions are not ideal: the Little Boy (gun type mechanism) and Fat Man (implosion type mechanism) bombs had efficiencies of 1.38% and 13%, respectively.

Fusion boosting is achieved by introducing tritium **and** deuterium gas. Solid lithium deuteride-tritide has also been used in some cases, but gas allows more flexibility (and can be stored externally) and can be injected into a hollow cavity at the center of the sphere of fission fuel, or into a gap between an outer layer and a "levitated" inner core, sometime **before implosion**. By the time about 1% of the fission fuel has fissioned, the temperature rises high enough to cause thermonuclear fusion, which produces relatively large numbers of neutrons, speeding up the late stages of the chain reaction and approximately **doubling its efficiency.**

Deuterium-tritium fusion neutrons are extremely energetic, **seven times** more energetic than an average fission neutron, which makes them much more likely to be captured in the fissile material and lead to fission. This is due to several reasons:

1. Their high velocity creates the opposite of time absorption: time magnification.
2. When these energetic neutrons strike a fissile nucleus, a much larger number of secondary neutrons are released by the fission (e.g. **4.6 vs 2.9 for Pu-239)**.
3. The fission cross section is larger both in absolute terms, and in proportion to the scattering and capture cross sections.

Taking these factors into account, the maximum alpha value for D-T fusion neutrons in plutonium (density 19.8 g/cm³) is some **8 times higher** than for an average fission neutron (2.5×10^9 vs 3×10^8).

A sense of the potential contribution of fusion boosting can be gained by observing that the complete fusion of one mole of tritium (3 grams) and one mole of deuterium (2 grams) would produce one mole of neutrons (1 gram), which, neglecting escape losses and scattering for the moment, could fission one mole (239 grams) of plutonium directly, producing 4.6 moles of secondary neutrons, which can in turn fission another 4.6 moles of plutonium (1,099 g). The fission of this 1,338 g of plutonium in the first two generations would release 23[4] kilotons of TNT equivalent (97 TJ) of energy, and would by itself result in a 29.7% efficiency for a bomb containing 4.5 kg of plutonium (a typical small fission trigger). The energy released by the fusion of the 5 g of fusion fuel itself is only 1.73% of the energy released by the fission of

1,338 g of plutonium. **Larger total yields and higher efficiency are possible**, since the chain reaction can continue beyond the second generation after fusion boosting.[5]

Fusion-boosted fission bombs can also be made immune to neutron radiation from nearby nuclear explosions, which can cause other designs to pre-detonate, blowing themselves apart without achieving a high yield. The combination of reduced weight in relation to yield and immunity to radiation has ensured that most modern nuclear weapons are fusion-boosted.

The fusion reaction rate typically becomes significant at 20 to 30 megakelvins. This temperature is reached at very low efficiencies, when less than 1% of the fissile material has fissioned (corresponding to a yield in the range of hundreds of tons of TNT). Since implosion weapons can be designed that will achieve yields in this range even if neutrons are present at the moment of criticality, fusion boosting allows the manufacture of efficient weapons that are immune to predetonation. Elimination of this hazard is a very important advantage in using boosting. It appears that every weapon now in the U.S. arsenal is a boosted design.[5] According to one weapons designer, boosting is mainly responsible for the remarkable **100-fold increase** in the efficiency of fission weapons since 1945.[6]

Neutron initiator[edit] These are devices incorporated in nuclear weapons which produce a pulse of neutrons when the bomb is detonated to initiate the fission reaction in the fissionable core (pit) of the bomb, after it is compressed to a critical mass by explosives. Actuated by an **ultrafast switch** like a krytron, a small particle accelerator drives ions of tritium and deuterium to energies above the 15 keV or so needed for deuterium-tritium fusion and directs them into a metal target where the tritium and deuterium are adsorbed as hydrides. High-energy fusion neutrons from the resulting fusion radiate in all directions. Some of these strike plutonium or uranium nuclei in the primary's pit, initiating nuclear chain reaction. The quantity of neutrons produced is large in absolute numbers, allowing the pit to quickly achieve neutron levels that would otherwise need many more generations of chain reaction, though still small compared to the total number of nuclei in the pit.

Boosting[edit] *Main article: Boosted fission weapon* Before detonation, a few grams of tritium-deuterium gas are injected into the hollow "pit" of fissile plutonium or uranium. The early stages of the fission chain reaction supply enough heat and compression to start deuterium-tritium fusion, then both fission and fusion proceed in parallel, the fission assisting the fusion by continuing heating and compression, and the fusion assisting the fission with highly energetic (14.1 MeV) neutrons. As the fission fuel depletes and also explodes outward, it falls below the density needed to stay critical by itself, but the fusion neutrons make the fission process progress faster and continue longer than it would without boosting. Increased yield comes overwhelmingly from the increase in fission. The energy released by the fusion itself is much smaller because the amount of fusion fuel is so much smaller. The effects of boosting include:

- increased yield (for the same amount of fission fuel, compared to detonation without boosting)
- the possibility of variable yield by varying the amount of fusion fuel
- allowing the bomb to require a smaller amount of the very expensive fissile material – and also eliminating the risk of predetonation by nearby nuclear explosions

- not so stringent requirements on the implosion setup, allowing for a smaller and lighter amount of high-explosives to be used

The tritium in a warhead is continually undergoing radioactive decay, hence becoming unavailable for fusion. Furthermore its decay product, helium-3, absorbs neutrons if exposed to the ones emitted by nuclear fission. This potentially offsets or reverses the intended effect of the tritium, which was to generate many free neutrons, if too much helium-3 has accumulated from the decay of tritium. Therefore, it is necessary to replenish tritium in boosted bombs periodically. The estimated quantity needed is 4 grams per warhead.[3] To maintain constant levels of tritium, about 0.20 grams per warhead per year must be supplied to the bomb.

One mole of deuterium-tritium gas would contain about 3.0 grams of tritium and 2.0 grams of deuterium. In comparison, the 20 moles of plutonium in a nuclear bomb consists of about 4.5 kilograms of plutonium-239.

Tritium in hydrogen bomb secondaries[edit] *See also: Nuclear weapon design* -- Since tritium undergoes radioactive decay, and is also difficult to confine physically, the much larger secondary charge of heavy hydrogen isotopes needed in a true hydrogen bomb uses solid lithium deuteride as its source of deuterium and tritium, producing the tritium *in situ* during secondary ignition.

Some early non-staged thermonuclear weapon designs[edit] -- Early thermonuclear weapon designs such as the Joe-4, the Soviet "Layer Cake" ("Sloika", Russian: Слойка), used large amounts of fusion to induce fission in the uranium-238 atoms that make up depleted uranium. These weapons had a fissile core surrounded by a layer of lithium-6 deuteride, in turn surrounded by a layer of depleted uranium. Some designs (including the layer cake) had several alternate layers of these materials. The Soviet *Layer Cake* was similar to the American *Alarm Clock* design, which was never built, and the British *Green Bamboo* design, which was built but never tested.

When this type of bomb explodes, the fission of the highly enriched uranium or plutonium core creates neutrons, some of which escape and strike atoms of lithium-6, creating tritium. At the temperature created by fission in the core, tritium and deuterium can undergo thermonuclear fusion without a high level of compression. The fusion of tritium and deuterium produces a neutron with an energy of 14 MeV—a much higher energy than the 1 MeV of the neutron that began the reaction. This creation of high-energy neutrons, rather than energy yield, is the main purpose of fusion in this kind of weapon. This 14 MeV neutron then strikes an atom of uranium-238, causing fission: without this fusion stage, the original 1 MeV neutron hitting an atom of uranium-238 would probably have just been absorbed. This fission then releases energy and also neutrons, which then create more tritium from the remaining lithium-6, and so on, in a continuous cycle. Energy from fission of uranium-238 is useful in weapons: both because depleted uranium is much cheaper than highly enriched uranium and because it cannot go critical and is therefore less likely to be involved in a catastrophic accident.

This kind of thermonuclear weapon can produce up to 20% of its yield from fusion, with the rest coming from fission, and is limited in yield to less than one megaton of TNT (4 PJ) equivalent. Joe-4 yielded 400 kilotons of TNT (1.7 PJ). In comparison, a "true" hydrogen bomb can produce up to 97% of its yield from fusion, and its explosive yield is limited only by device size.

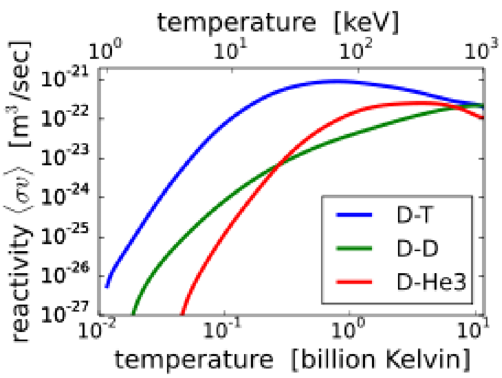
Maintenance of gas boosted nuclear weapons[edit]

Tritium is a radioactive isotope with a half-life of **12**.355 years. Its main decay product is Helium-3, which has the largest cross-section for neutron capture of any nuclide. Therefore, periodically the weapon must have its helium waste flushed out and its tritium supply recharged. This is because any helium-3 in the weapon's tritium supply would act as a poison during the weapon's detonation, absorbing neutrons meant to collide with the nuclei of its fission fuel.[7]

Tritium is relatively expensive to produce because each triton produced requires production of at least one free neutron which is used to bombard a feedstock material (lithium-6, deuterium, or helium-3). Actually, because of losses and inefficiencies, the number of free neutrons needed is closer to two for each triton produced (and tritium begins decaying immediately, so there are **losses** during collection, storage, and transport from the production facility to the weapons in the field.) The production of free neutrons demands the operation of either a breeder reactor or a particle accelerator (with a spallation target) dedicated to the tritium production facility.[8][9] -- Nuclear Weapons Archive: http://nuclearweaponsarchive.org

https://en.wikipedia.org/wiki/Fusion_power#D-T_fuel_cycle,

There is in addition one authorized copy of on out-dated version of the NWFAQ at **www.milnet.com** that has been "grandfathered" for the present time.



12.0 Useful Tables

CONVERSION FACTORS

Unit	Equivalent To
1 kt	10^12 calories
	4.19x10^12 joules
	4.19x10^19 ergs
	2.62x10^31 eV
	2.62x10^25 MeV
	fission of 0.241 moles of material (1.45x10^23 nuclei)
	fission of approx. 57 g of material
	1.16x10^6 kilowatt-hrs
	3.97x10^9 BTU
1 eV	1.602177 x 10^-12 erg
	11606 degree K
1 Bar	10^5 pascals (nt/m^2)
	10^6 dyne/cm^2

	0.98687 atmospheres
	14.5038 PSI
1 calorie	4.1868 J

Convenient Energy Content Approximations
Fission of U-233: 17.8 kt/kg
Fission of U-235: 17.6 kt/kg
Fission of Pu-239: 17.3 kt/kg
Fusion of pure deuterium: 82.2 kt/kg
Fusion of tritium and deuterium (50/50): 80.4 kt/kg
Fusion of lithium-6 deuteride: 64.0 kt/kg
Fusion of lithium-7 deuteride
Total conversion of matter to energy: 21.47 Mt/kg
Fission of 1.11 g U-235: 1 megawatt-day (thermal)

IMPORTANT UNITS OF MEASUREMENT

Quantity Measured	Unit	Symbol	Formula
Microscopic Cross Section	Barn	b	10^-24 cm^2
Radioactivity	Becquerel	Bq	1 decay/sec
	Curie	Ci	3.7x10^10 decay/sec
Absorbed Radiation Dose	Gray	Gy	1 J/Kg
	Rad	None	100 erg/g (.01 J/Kg)
Biological Equivalent Dose	Sievert	Sv	Grays*Q
	Rem	None	Rads*RBE
Absorbed Gamma/X-Ray Dose	Roentgen	R	94 erg/g
Immediate Explosive Energy	Kiloton	kt	10^12 calories
Radiation Biological Effect	None	RBE	
Radiation Quality Factor	None	Q	
Pressure	Bar	None	10^5 pascals (nt/m^2)

PHYSICAL CONSTANTS
[All constants are exact to the precision given]

Quantity	Symbol	Value	Unit
Speed of Light in Vacuum	c	2.99792458 x 10^10	cm/sec
Planck Constant	h	6.62608 x 10^-27	erg-sec
Avogadro Constant	N_A	6.02214 x 10^23	atom/mole
Molar Gas Constant	R	8.3145 x 10^7	erg/(mole K)
Boltzmann Constant	k	1.3806 x 10^-16	erg/K
Stefan-Boltzmann Constant	sigma	5.670 x 10^-5	erg/cm^2 K^4 sec
Perfect Gas Standard Volume	V_0	2.2414 x 10^5	cm^3
Atomic Mass Constant	m_0	1.66054 x 10^-24	g
	m_0	9.31494 x 10^8	eV

According to one weapons designer, boosting is mainly responsible for the remarkable 100-fold increase in the efficiency of fission weapons since 1945.[6] When this type of bomb explodes, the fission of the highly enriched uranium or plutonium core creates neutrons, some of which escape and strike atoms of lithium-6, creating tritium. At the temperature created by fission in the core, tritium and deuterium can undergo thermonuclear fusion without a high level of compression. The fusion of tritium and deuterium produces a neutron with an energy of 14 MeV—a much higher energy than the 1 MeV of the neutron that began the reaction. This creation of high-energy neutrons, rather than energy yield, is the main purpose of fusion in this kind of weapon. This 14 MeV neutron then strikes an atom of uranium-238, causing fission: without this fusion stage, the original 1 MeV neutron hitting an atom of uranium-238 would probably have just been absorbed. This fission then releases energy and also neutrons, which then create more tritium from the remaining lithium-6, and so on, in a continuous cycle. Energy from fission of uranium-238 is useful in weapons: both because Tritium is a radioactive isotope with a half-life of **12.**355 years. Its main decay product is Helium-3, which has the largest cross-section for neutron capture of any nuclide. Therefore, periodically the weapon must have its helium waste flushed out and its tritium supply recharged. This is because any helium-3 in the weapon's tritium supply would act as a poison during the weapon's detonation, absorbing neutrons meant to collide with the nuclei of its fission fuel.[7]

Tritium is relatively expensive to produce because each triton produced requires production of at least one free neutron which is used to bombard a feedstock material (lithium-6, deuterium, or helium-3). Actually, because of losses and inefficiencies, the number of free neutrons needed is closer to two for each triton produced (and tritium begins decaying immediately, so there are losses during collection, storage, and transport from the production facility to the weapons in the field.) The production of free neutrons demands the operation of either a breeder reactor or a particle accelerator (with a spallation target) dedicated to the tritium production facility.[8][9]

A sense of the potential contribution of fusion boosting can be gained by observing at 1.5 g of tritium (half an atom mole) will produce sufficient neutrons to fission 120 g of plutonium directly, and 660 g when the secondary neutrons are taken into account. This would release 11.6 kt of energy, and would by itself result in a 14.7% overall efficiency for a bomb containing 4.5 kg of plutonium (a typical small fission trigger). The fusion energy release is just 0.20 kt, less than 2% of the overall yield. Larger total yields and higher efficiency is possible of course, since this neglects the fission-only chain reaction required to ignite the fusion reaction in the first place and that fission multiplication would continue significantly beyond the fissions caused by the fusion induced secondaries.

The fusion reaction rate is proportional to the square of the density at a given temperature, so it is important for the fusion fuel density to be as high as possible. The higher the density achieved, the lower the temperature required to initiate boosting. Lower boosting initiation temperatures mean that less pre-boost fission is required, allowing lower alpha cores to be used.
Nuclear weapon design   Thermonuclear weapon

References[edit]

1. **Jump up ^** "Facts about Nuclear Weapons: Boosted Fission Weapons", Indian Scientists Against Nuclear Weapons Archived July 8, 2008, at the Wayback Machine.
2. **Jump up ^** Rhodes, Richard, *Dark Sun*: The Making of the Hydrogen Bomb*, New York, Simon & Schuster (1996)*
3. **Jump up ^** *Bethe, Hans A. (28 May 1952). Chuck Hansen, ed. "Memorandum on the History Of Thermonuclear Program". Federation of American Scientists. Retrieved 19 May 2010.*
4. **Jump up ^** *"Nuclear Weapon Archive: 12.0 Useful Tables".*
5. ^ Jump up to: *a b "Nuclear Weapon Archive: 4.3 Fission-Fusion Hybrid Weapons".*
6. **Jump up ^** *Olivier Coutard (2002). The Governance of Large Technical Systems. Taylor & Francis. p. 177.*
7. **Jump up ^** *"Section 6.3.1.2 Nuclear Materials Tritium". High Energy Weapons Archive FAQ. Carey Sublette. Retrieved June 7, 2016.*

8. **Jump up ^** *"Section 6.3.1.2 Nuclear Materials Tritium". High Energy Weapons Archive FAQ. Carey Sublette. Retrieved June 7, 2016.*
9. **Jump up ^** *"Section 4.3.1 Fusion Boosted Fission Weapons". High Energy Weapons Archive FAQ. Carey Sublette. Retrieved June 7, 2016.*

6.3.1 Hydrogen Isotopes Hydrogen was identified as a distinct substance by Henry Cavendish in 1766, and was named by Antoine Laurent Lavoisier. Natural hydrogen consists of two isotopes: H-1 (light hydrogen or protium), and deuterium (D, H-2, heavy hydrogen) which occurs in nature in a concentration of 0.015% (one atom in 6760 of light hydrogen). Light hydrogen participates in fusion reactions extremely slowly (that's why the sun is still around). Deuterium fuses much more readily. In the smallest stars, known as brown dwarfs, only deuterium fusion can occur and once this is exhausted the star becomes inert and planet-like. All of the deuterium in the universe today was created in the first three minutes of the Big Bang, it has been slowly depleted by stellar burning. The unstable super heavy isotope tritium rapidly decays and thus exists in nature only in minute quantities.

In elemental form all hydrogen isotopes are gases with very low densities and boiling points. This often makes them inconvenient to incorporate into practical weapons, so lithium deuteride/tritide compounds are frequently used. *6.3.1.1 Deuterium (D)*
This natural isotope was discovered by American chemist Harold C. Urey and his associates F.G. Brickwedde and G.M. Murphy in 1931. Urey was awarded the Nobel Prize for Chemistry for this achievement in 1934. Urey had predicted a vapor pressure difference between the molecular hydrogen (H2) and of a corresponding molecule with one hydrogen atom replaced by deuterium (HD) and, thus, the possibility of separating these substances by distillation of liquid hydrogen. The deuterium was detected (by its atomic spectrum) in the residue of a distillation of liquid hydrogen.

Deuterium was first prepared in pure form in 1933 by G.N. Lewis, using the electrolytic method of concentration discovered by E.W. Washburn. When water is electrolyzed--i.e., decomposed by an electric current (actually a water solution of an electrolyte, usually sodium hydroxide, is used)--the hydrogen gas produced contains a smaller fraction of deuterium than the remaining water, and, hence, deuterium is concentrated in the water. Very nearly pure deuterium oxide is obtained when the amount of water has been reduced to about **one hundred-thousandth of its original volume** by continued electrolysis. This was the standard method of preparation of D2O before World War II. Deuterium is twice as heavy as hydrogen-1, a fact that is very noticeable in the elemental state. Deuterium oxide, D2O, is commonly called "heavy water".