Hydrogen Bomb vs Coughing Baby

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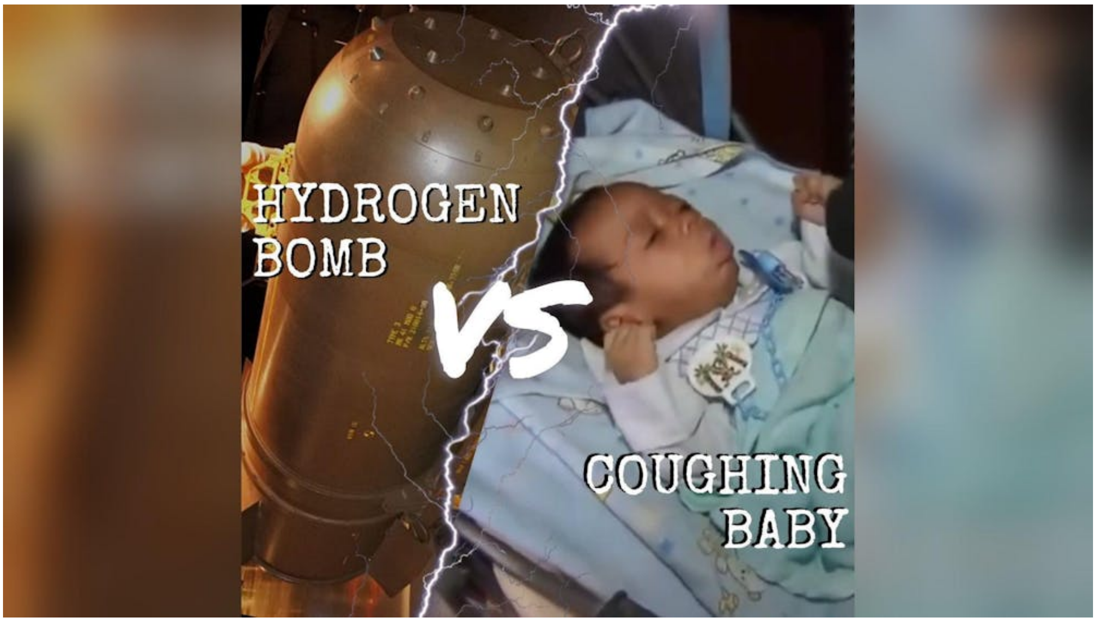
Introduction and disclaimer

The following essay is purely for fun and an exploration of an interesting internet meme. I do not endorse or encourage any real-world recreation of the scenario described below and strongly discourage anyone attempting to test this in real life, for obvious reasons. More importantly, this essay should serve as an admonition about how powerful a nuclear bomb actually is and the destruction it can inflict to nature and humans in general and advocate for full nuclear disarmament on earth.

In this essay, I will attempt to explore how many coughing babies are needed to survive a hydrogen bomb?

This idea stems from a popular Gen Z internet meme used as a shorthand for two things of wildly unequal power facing off.[1]



Assumption

1. The winning condition for the coughing baby is for at least one baby to survive a detonation of a hydrogen bomb.

Explanation: If one of the babies survived, they had defended themself and are therefore considered victorious.

2. We will use the hydrogen bomb named Castle Bravo for a representation of a Hydrogen bomb.

   Explanation: We have no way of knowing all the data for every single type of hydrogen bomb and it is also well documented with accurate data.

3. We assume the coughing child is an average one year old child.

   Explanation: This is necessary for simplification and any complication of the child will not make a significant difference for the accuracy of the result.

4. For the baby to win, they must absorb and contain all the effects of the explosion of the hydrogen bomb.

   Explanation: A baby can survive a bomb blast and its effect if they are sufficiently far away from the blast point, however, survival at a distance wouldn't constitute a true battle against the bomb's full energy output, therefore, they must absorb all effects of the bomb.

5. Babies can be realistically modeled by typical ballistic gelatine.

   Explanation: Ballistic gelatin is used in many experiments in the scientific world to model blast effect on human soft tissue because its molecular structure is similar to that of human's soft tissues, making it a suitable way to model the effect of the explosion on the babies.

6. The "battleground" will be in space.

   Explanation: This is to simplify the problem, interactions with Earth like atmospheric pressure and gravity will only complicate the problem.

Variables

Symbol	Definition	Units
E_h	Energy from heat store	J
T_v	Final temperature	K
T_i	Initial temperature	K
C	Specific heat capacity	J/K/kg
L_v	Latent heat of vaporisation	J/kg
L_f	Latent heat of fusion	J/kg
ρ	Density of water	kg/m^3
V	Volume of gelatine melted by heat	m^3
t	Original thickness of wall surrounding cavity melted by heat	m
t_s	Stretched thickness of wall surrounding cavity melted by heat	m
r	Original radius of cavity melted by heat	m
r_s	Stretched radius of cavity melted by heat	m
P_i	Internal pressure	Pa
P_e	External pressure	Pa
n	Number of moles of gas	mol
R	Gas constant	n/a
T	Temperature	K
σ	Hoop stress experienced in the wall	Pa
λ	Stretch ratio (r_s/r)	n/a
G	Shear modulus of the material	Pa
M	Molar mass	kg/mol
m	Mass	kg

Model Creation

The best way to absorb all energy released by the nuclear bomb is to surround the bomb with babies in a spherical fashion. This would form a protective shield around the bomb and contain the radioactive material and hopefully keep some babies on the outside alive after the blast.

In the following model, we expect the heat from the bomb will melt the babies closer to the point of explosion, which will form a cavity around the bomb. However, the increase in energy in the system inside the cavity will cause the pressure inside the cavity to increase and stretch the external wall like a balloon would.

How the Bomb Works

To find a way for the baby to win, we must first understand how the hydrogen bomb works. A hydrogen bomb fuses small molecules together to produce a larger molecule, where some mass is converted into energy usually in the form of Gamma radiation.

Total energy released by bomb

The hydrogen bomb Castle Bravo yielded 15 megatons of TNT [2]. This is equivalent to

$$15 \times 4.184 \times 10^{15} = 6.276 \times 10^{16} \text{ J}$$

of energy (conversion factor 4.184×10^{15} J per megaton of TNT).

This bomb's energy can be roughly split into 3 parts: kinetic (shockwaves), thermal (heat), and radiation (primarily gamma radiation). The share of energy can be roughly found in the following ratio of 50%, 35%, and 15% respectively.[4]

Radiation energy

Radiation energy is the energy released through space or material medium in the form of electromagnetic waves. Approximately a third of the energy released through radiation energy is released gradually during the later fallout period of a nuclear event. Since we are only modelling the immediate effects of the blast, the 5% of total yield released gradually as fallout radiation is excluded from our calculations.

Kinetic (shockwaves)

Some energy from the nuclear bomb is released in the form of a shockwave from a sudden increase in pressure. This shockwave will pass through the walls of babies and be attenuated by the materials. The energy dissipated from the shock waves will be transferred into heat and thermal energy. Since the energy escaping to the outside of the baby sphere is relatively small, we can safely assume that all of the energy from the kinetic store is released into heat energy.

Thermal energy

Some energy is released into heat. This will heat up the babies and melt them. Per assumption 5, the gelatine will heat up and melt then evaporate. This will transfer the thermal energy into kinetic energy. 95% of all energy released by the bomb will be converted into thermal energy (since the remaining 5% is carried away as radiation and does not contribute to heating), as energy naturally disperses as heat in accordance with the second law of thermodynamics.

Thermal energy will be used in 2 ways:

Energy for melting (fusion) and evaporating (vaporisation)

Since the initial state for gelatine is solid, energy must be used to overcome the intermolecular bonds when changing states. This energy is called latent heat.

There are two types of latent heat: latent heat of fusion and latent heat of vaporisation, which are defined as the energy needed for 1 kg of a material to change states from solid to liquid and from liquid to gas form respectively.

Latent heat can be calculated with:

$$E = mL$$

Energy for increase in temperature

Thermal energy will increase the speed of the particles and therefore heat them up. This can be calculated with the following equation:

$$E = mC(T_v - T_i)$$

This can be added to the energy lost to latent heat to get the following equation:

$$E_h = [(T_v - T_i) \cdot C + L_v + L_f] \cdot m$$

Substituting the density equation for m:

$$\rho = m/V_i \implies E_h = [(T_v - T_i) \cdot C + L_v + L_f] \cdot \rho \cdot V_i$$

Because a material will still act against pressure until they are evaporated, we can assume the average final temperature to be the boiling point of the gelatine blocks since after they are evaporated, they will no longer act as a barrier against the internal pressure and will be displaced as part of the cavity created by the bomb.

Substituting the following values [9][10]:

Variable	**Value (unit)**
E_h	$6.276 \times 10^{16} \times 0.95 = 5.96 \times 10^{16}$
T_v	423.15 K
T_i	298.15 K
C	4351.36 J/kg/K
L_f	300195 J/kg
L_v	2.26×10^6 J/kg
ρ	1027 kg/m^3

We can get:

$$V_i = 1.921 \times 10^7 \text{ m}^3$$

This is roughly the volume of a small lake.

Internal pressure

Since the gelatine inside the cavity will be evaporated into gas, pressure can be calculated with the ideal gas formula:

$$PV = nRT$$

This can be rearranged into:

$$P = nRT/V$$

Moles can be converted into mass through the molar mass formula:

$$n = m/M$$

This can then be substituted into the ideal gas formula to get:

$$P = mRT/MV$$

Substituting into the density formula:

$$P = \rho RT/M$$

External pressure

For a thin-walled sphere under internal pressure, the Hoop stress formula can be used to determine the relationship between volume and pressure:

$$\Sigma = P \cdot r_s/(2t_s)$$

Rearranging for P:

$$P = 2\sigma t_s/r_s$$

Because the volume remains constant, the stretched wall will have the same volume as the unstretched wall. We can therefore determine that:

$$t_s \cdot r_s^2 = t \cdot r^2$$

Rearranging and substituting $\lambda = r_s/r$:

$$t = t_s \cdot \lambda^2 \implies t/\lambda^2 = t_s$$

Substituting it into the equation for pressure:

$$P = 2\sigma t/\lambda^2 \cdot \lambda \cdot r \implies P = 2t\sigma/r\lambda^3$$

Assuming the gelatine wall is incompressible we can use a neo-Hookean model to predict the result of the stretching:

$$\sigma = G(\lambda^2 - 1/\lambda^4)$$

Substituting in and simplifying:

$$P(\lambda) = 2tG(1/\lambda - 1/\lambda^7)/r$$

This equation shows the relationship between pressure and the stretching of the wall. However, we need to find the maximum pressure in order to determine the minimum volume of wall needed to contain the pressure. Plotting $P(\lambda)$, we determine that it rises, peaks, then falls due to geometric softening in balloons. Therefore, to find the maximum pressure it can withstand, we just have to take the derivative of $P(\lambda)$ and equate it to zero. Setting the derivative to zero gives the stretch ratio at maximum pressure.

$$\frac{d}{d\lambda}\left(\lambda^{-1} - \lambda^{-7}\right) = -\lambda^{-2} + 7\lambda^{-8} = 0$$

We can then solve this and determine that the maximum pressure occurs at $\lambda = 7^{1/6} \approx 1.383$.

Substituting this into $P(\lambda)$, we can get the following equation:

$$P = 2 \cdot t_0 \cdot G \cdot 0.6197/r$$

This is the equation for maximum pressure before material starts to deform.

Equilibrium

Imagine the wall surrounding the cavity as behaving like a balloon. The balloon will only stop moving if the inward pressure is in equilibrium to the outward pressure where there is no force acting on the surface of the balloon. Therefore, equilibrium will occur when pressure inward is the same and pressure outward is equal. We can therefore equate our two equations:

$$P_E = 2 \cdot t_0 \cdot G \cdot 0.6197/r$$
$$P_i = \rho RT/M$$
$$1.239\, t\, G/r = \rho RT/M$$

For a relatively thin wall of a sphere, the volume can be approximated at:

$$V_E = t_0 \cdot 4\pi r^2$$

This can be rearranged into:

$$V_E/(4\pi r^2) = t$$

Substituting in for t:

$$1.239 \cdot V_E \cdot G/r \cdot 4\pi r^2 = \rho RT/M$$

Using the following constants [5][6][7][8]:

Variable	Value (unit)
G	3400 Pa
ρ	1027 kg/m^3
R	8.31441 J K^{-1} mol^{-1}
M	0.018015 kg/mol

We can deduce the following equation:

$$V_E = 1413.9 \cdot T \cdot r^3$$

The internal volume is defined as:

$$V_i = \frac{4}{3}\pi r^3$$

Rearranging gives:

$$3V_i/4\pi = r^3$$

Substituting into r^3:

$$V_E = 1413.9 \cdot T \cdot 3V_i/4\pi \implies V_E = 337.54 \cdot T \cdot V_i$$

Substituting into the following values found above:

Variable	**Value (unit)**
V_i	1.921×10^7 m^3
T_v	423.15 K

Solving for V_E:

$$V_E = 2.743 \times 10^{12}$$

However, we need to find the total number of babies needed for both external and internal volume. We can simply add the volumes together:

$$V_i + V_E = 2.743 \times 10^{12}$$

A baby has an average volume of 0.01 m^3:

$$= 2.743 \times 10^{12}/0.01$$

$$= \underline{2.743 \times 10^{14}} \text{ babies needed.}$$

$$= 274.3 \text{ trillion babies}$$

Exploration of data

This is equivalent to 33000 times Earth's current population (≈8 billion) and if you stack the babies on top of one another, you can stack a tower from the Earth to the Sun 4793 times (∼150 million km). If gelatine blocks are used, it will cost £5.5 quadrillion, which costs 59 times the world's GDP.

Weaknesses of model

As with any simplified model, there are important limitations to acknowledge. The model does not account for the reduction in the strength of gelatine as temperature increases. Cracks forming at the junctions between the babies would weaken the overall structure of the cavity wall. Radiation leakage is another concern. Even if energy and pressure are fully contained, gamma radiation could still penetrate the walls, potentially causing radiation sickness in the babies on the outer layers. While gelatine is a reasonable substitute for human soft tissue, the model assumes that babies have identical physical properties. In reality, babies may differ in properties such as specific heat capacity and shear modulus, which could affect the results. Finally, the model assumes a thin cavity wall, whereas the results indicate that this assumption may not hold. This discrepancy could have skewed the outcomes of the analysis.

Summary

Finally, it is important to reiterate that this is just a fun exploration of an interesting internet topic and I do not endorse and strongly condemn any harm caused to any human beings. This also serves as a vehement warning against nuclear weapons of mass destruction and promotes nuclear disarmament because of the potential damage it can cause to the environment and human beings.

References

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