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(1)(i) For ignition and high burn there are two ρr criteria

a) $\rho r > 0.3$ g/cm^2 for a hot spot

b) $\rho r > 3.0$ g/cm^2 for a whole fuel blob

(ii) compression = 50 times

$\rho_0 = 0.22$ g/cm^3,

$\rho' = 50 \times 0.22 =$ 11 g/cm^3

From $f_b = \frac{\rho r}{7 + \rho r} \Rightarrow \rho' r = \frac{7 \times f_b}{1 - f_b}$

$\rho' r = \frac{7 \times 0.33}{1 - 0.33} =$ 3.449 g/cm^2

$r = 3.449/11 =$ 0.3135 cm

$V = \frac{4}{3}\pi \times r^3 = \frac{4}{3}\pi (0.3135)^3 =$ 0.129 cm^3

$M = \rho' \cdot V = 11 \times 0.129 =$ 1.420 g

$W_{released} = f_b \times Q \times m =$

$= 0.33 \times 3.3 \times 10^{11} \times 1.420 = 1.55 \times 10^{11}$ J = 155 GJ

For compression = 2,000 times

$\rho' = 2{,}000 \times 0.22 =$ 440 g/cm^3

$r = 3.449/440 =$ 0.00784 g

$V = 4/3\ \pi \times (0.00784)^3 =$ 2.02×10^{-6} cm^3

$m = \rho' \times V = 440 \times 2.02 \times 10^{-6} =$ 8.88×10^{-4} g

$W_{released} = 0.33 \times 3.3 \times 10^{11} \times 8.88 \times 10^{-4} =$ 96 MJ

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For a hot spot ρr criteria is $\rho r > 0.3\ g/cm^2$

$r = 0.3/100 = \underline{3\times10^{-3}\ cm}$

$V = \frac{4}{3}\pi \times (3\times10^{-3})^3 = \underline{1.13\times10^{-7}\ cm^3}$

$m = \rho V = 100 \times 1.13\times10^{-7} = \underline{1.13\times10^{-5}\ g}$

$W_{req} = 100\times10^{6}\times1.13\times10 = \underline{1.13\times10^{4}\ J}$

$= 11.3\ KJ$

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(2) Total mass of fusion fuel

$m_f = \frac{1\ GJ}{(3.3\times10^{11}\times 60\%)} = 5\times10^{-3}\ g = \underline{5\times10^{-6}\ kg}$

Mass of TNT fuel

$m_{TNT} = 1\ GJ/4.6\ MJ = \underline{217.4\ kg}$

$E = \frac{1}{2}mv^2 = \frac{1}{2}\frac{m^2v^2}{m} = \frac{1}{2}\frac{p^2}{m} \Rightarrow p = \sqrt{2mE}$

$P_f = \sqrt{2\times5\times10^{-6}\times10^{9}} = \underline{100\ kg\cdot M/c}$

$P_{TNT} = \sqrt{2\times217.4\times10^{9}} = \underline{6.6\times10^{5}\ kg\frac{M}{c}}$

$P_{TNT}/P_f = 6.6\times10^{5}/100 = \underline{6,600\ times}$

$\frac{P_{TNT}}{P_f} = \frac{\sqrt{2m_{TNT}E}}{\sqrt{2m_fE}} = \sqrt{\frac{m_{TNT}}{m_f}} = \sqrt{\frac{217.4}{5\cdot10^{-6}}} = \underline{6,600\ times}$