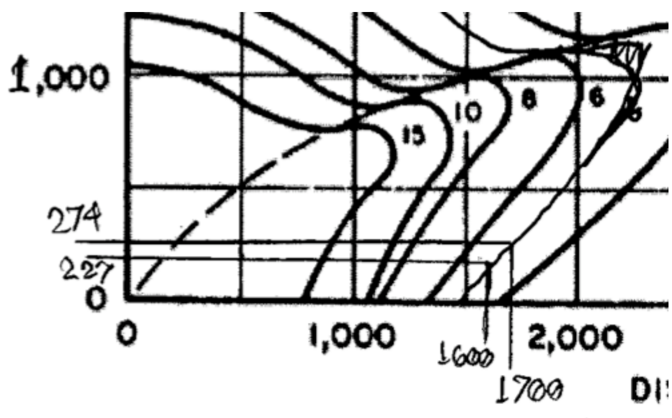
Calculating Nuclear Weapons Effects – Solutions

1. Since this problem deals with blast effects, we refer to the overpressure charts. Before using them, however, we have to first scale the height of burst to the 1-kt equivalent yield. This is:

$$H_{1-\text{kt}} = \frac{H_{57-\text{Mt}}}{\sqrt[3]{57,000}} = \frac{10,560}{46.4} = 274 \text{ ft}$$

   That is, the blast effects would be the same as a 1-kt bomb exploded only 274 ft above the ground. From this height-of-burst on the low-overpressure chart (below), we read across and find the distance from ground zero corresponding to 5 psi, which is 1700 ft. The equivalent distance for a 57-Mt blast would therefore be $R_{5 \text{ psi}} = (1700)\sqrt[3]{57,000} = 65,424$ ft. This is $\boxed{R_{5 \text{ psi}} = \frac{65,424}{5280} = 12.4 \text{ miles!}}$ The blast area is therefore $\boxed{A_{\text{blast}} = \pi R_{5 \text{ psi}}^2 = (3.14)(12.4)^2 = 483 \text{ square miles!}}$



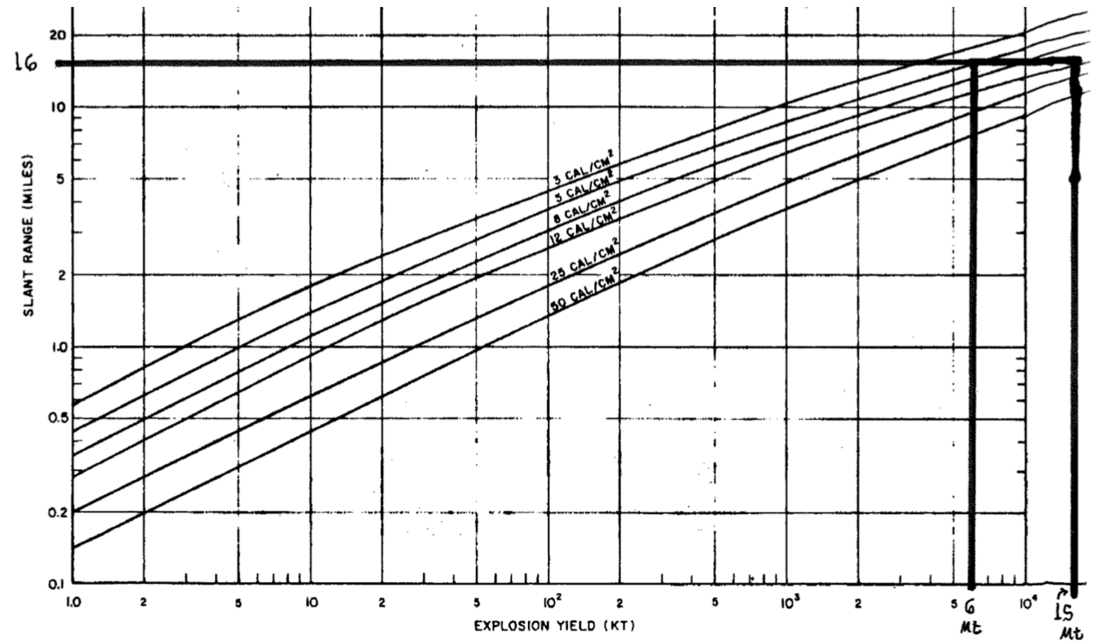
2. If the 100 Mt bomb is exploded at 10,560 ft, the scaled height-of-burst will be

$$H_{1-\text{kt}} = \frac{H_{100-\text{Mt}}}{\sqrt[3]{100,000}} = \frac{10,560}{46..4} = 227 \text{ ft}$$

   This is lower than in Question 1 because of the Mach effect. The 5 psi distance for 1-kt is about 1600 ft, as read from the chart at this height-of-burst. So, for a 100 Mt bomb (or 100,000-kt yield), the equivalent blast radius is: $R_{5 \text{ psi}} = (1500)\sqrt[3]{100,000} = 74,265$ ft. This is $\boxed{R_{5 \text{ psi}} = \frac{74,265}{5280} = 14.1 \text{ miles}}$. This isn't significantly different from the previous radius, even though the yield is almost increased by a factor of 2. Again, this is due to the Mach effect and optimal height-of-burst.

3. Consulting the radiant exposure chart (see below), we find the slant range for a 6-Mt explosion that will produce 5 cal/cm^2, which is about 16 miles. Note that since the explosion is a surface burst, this distance is the same as the distance

from ground zero (no Pythagorean theorem required!). Since in reality this was a 15 Mt burst, we follow the chart horizontally over to see what the exposure from a 15 Mt blast would have been. This is, literally, off the chart! But we can take a guess of what it might be: for 10 Mt, it would be about 8 cal/cm^2, and for 15 Mt, probably about 12 cal/cm^2. So, if the scientists were unsheltered, they would likely have received 3rd degree burns!



4. (a) Each fission releases 200 MeV of energy, which is roughly 10^{-11} Joules. The molar mass of U-235 is 235 g, so in 57 g of U-235 there are $\frac{57}{235} = 0.24$ moles of atoms, or $0.24 \times 6 \times 10^{23} \sim 10^{23}$ atoms. So, 1 kt yield must correspond to the complete fissioning of 10^{23} atoms, with an energy of $200 \times 10^{23} \sim 10^{25}$ MeV. Since 1 MeV $= 10^{-13}$ Joules, the 1-kt yield releases 10^{25} MeV $\times 10^{-13} \frac{\text{Joules}}{\text{MeV}} \sim 10^{12}$ Joules. The 500 kt yield therefore released $\boxed{5 \times 10^{14} \text{ Joules.}}$

   (b) If 1-kt corresponds to 57 g of uranium, then 500-kt corresponds to 500×57 g $= 28,500$ g, or 28.5 kg. This means the percentage of the core that fissioned was $\frac{28.5}{60} = 0.475$, or $\boxed{47.5\% \text{ – just under half}}$.