Why the Ground Zero of WTC buildings stayed hot so long?

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François Roby in [1] presented calculations supporting Dimitry Khalazov's theory that three WTC buildings in New York were destroyed by nuclear controlled demolition on 9. September 2001. Yet, his last comments in the paper draw attention to several unsolved issues in the theory. These issues include the seismic signals, which do not match with expected much stronger signals from nuclear explosions, lack of major radioactive fallout, and most notably, a lack of craters. Seismic signals may be questioned as they have some other problems in addition to this one. Radioactive fallout may not be a fatal problem in the theory as newer weapons may have smaller fallout and radioactive material may have remained in the cavity deep in the ground. I consider the lack of putative craters as a serious problem, but there may be ways to explain it. For instance, it may be possible that the crust did not break all the way to the surface but only lifted the surface level up for a very short time causing a shock wave. Despite of these possibilities, I think it is useful to consider an alternative to the nuclear demolition theory. I will try to outline such a theory here.

The problem addressed in Roby's paper is the high temperatures in the Ground Zero of all three collapsed WTC buildings as recorded in area thermal images. Immediately after the attack infrared photos show hot spots of 1000 °C. Hot spots are seen in thermal images from 7. October 2001, that is 27 days after 9. September 2001. It has been announced that last fires were extinguished in 100 days since the attack. Normal fires do not usually last so long.

Roby derives a rough estimate for the initial heat transfer rate of the three WTC towers through free convection by air as 70 MW. The total area of the footprints of the towers was 12,000 m^2 and he estimates the temperature gradient as 350 K. By assuming that heat transfer power stays as 70 MW for four months (10^7 s) Roby obtains a rough estimate for the total energy that escaped through free convection by air as $7*10^{14}$ J. From this figure he concludes that only large nuclear explosions can give energy on this range. The rest of the paper investigates nuclear demolition.

Is his estimate reasonable? From the values given, Roby's estimate for heat transfer constant for free convection by air is h_c=17 W/m^2K. Literature gives a wide range of values for h_c for this special case ranging from 0.5 to 1000 W/m^2K, but Roby justifies his value by calculating it from definitions. His estimate for h_c is not in contradiction to what can be expected. The heat transfer constant cannot be close to the lower bound: for instance, fire brigades cooled the area by water, in Roby's method, where the only cooling method is free convection by air, this cooling by water must be modeled by a larger h_c. I think his estimate can be accepted, but his conclusions that this energy must come from an explosion, it not necessarily warranted.

There was quite much combustible material. Some of it burned as demonstrated by the fires. This material is responsible for some part of the total energy.

The floor area in WTC1 and 2 was about 350,000 m^2 and WTC7 had about 200,000 m^2. Thus the three towers together had the floor area 900,000 m^2. The NIST in WTC7 report [2] gives 20 kg/m^2 on floors 7 to 9 and 32 kg/m^2 on floors 11 to 13 as estimates for combustible material. Energy density of wood is about 18 MJ/kg and this value can be used for paper and furniture. If all combustible material burned, it would release the energy

$$E=3.2 *10^{14} \text{ J} - 5.2 *10^{14} \text{ J}.$$

Additionally there was 3,500 gallons (13,200 liters, 10,600 kg) of jet fuel in each plane. Kerosine has energy density of about 43 MJ/kg. This adds $9*10^{11}$ J, so it is ignorable in the total. There were two 6,000 gallon diesel tanks in WTC7. Together they are some 38,000 kg of diesel fuel. Diesel has energy density 32-40 MJ/kg. At most it gives $15*10^{11}$ J and is also ignorable in the total energy. The energy estimate from office material, however, is very close to the rough estimate Roby obtained. In principle this material could account for all energy dissipated through free convection by air, but the question is: how could this material burn totally? It requires oxygen from the air for burning and when oxygen is out, fire goes out and the site cools. There cannot have been enough oxygen inside the rubble for all material to burn.

Yet, there may be a way. Oxygen gets replaced by diffusion from the air. The rubble pile was not necessarily tight: there were lots of air pockets. Thus, oxygen could be replaced and fire could be started again, but only with the assumption that there was something very hot that could restart the fire. It cannot be normal fires. They burn off after some time and the site cools. They do not restart easily, but assuming that there was a very hot spot underground from which heat transferred through steel structures, we may find a possibility for fire to restart later. The transfer mechanism would be conduction: there is little possibility for convection in a rubble pile and radiation would not transfer heat far in the rubble pile. Furthermore, this conduction would be through steel structures, not through concrete. Steel has about ten times higher heat conductivity than concrete, and concrete in the pile would be fractured with air gaps between solid material further decreasing conductivity.

Is this mechanism possible? Let us make some calculations.

Let us assume that initially there is an underground spherical cavity with the radius r_0 and this cavity is at the temperature T_0. It will cool to the ambient temperature T_∞ by heat spreading to the outside of the cavity. In this special case we can assume that the cooling method is (at least mainly) by conduction. The temperature $T(r,t)$ depends on two parameters, the radius r and the time t. Fourier's Law gives the heat transfer power:

$$Q = -kA\frac{\partial T}{\partial r} \qquad (1)$$

The area A for a ball surface is $4\pi r^2$, but we assume that conduction happens through steel structures that constitute only a fraction of the whole surface. We can insert this condition by setting the area to $A(r) = \frac{4\pi}{\alpha} r^2$, where $1/\alpha$ is the fraction of steel structures of the whole ball surface. Energy is conserved, thus for each ball surface of radius r the value of Q is the same. Then

$$\frac{\partial T}{\partial r} = -\frac{Q\alpha}{4\pi k}\frac{1}{r^2} \quad \text{and} \quad T = \frac{Q\alpha}{4\pi k}\frac{1}{r} + T_\infty = \frac{Q\alpha}{4\pi k r_0}\frac{r_0}{r} + T_\infty .$$

Because

$$T_0 = T(r_0,0) = \frac{Q\alpha}{4\pi k r_0} + T_\infty \ ,$$

we can eliminate the term with Q and write

$$T(r,0) = T(r_0,0)\frac{r_0}{r} + T_\infty\left(1 - \frac{r_0}{r}\right)$$

but Fourier's Law holds for every t, not only for $t = 0$, thus

$$T(r,t) = T(r_0,t)\frac{r_0}{r} + T_\infty\left(1 - \frac{r_0}{r}\right), \ r \geq r_0 . \qquad (2)$$

Regardless of what cooling mechanism is used, conduction, convection or radiation, heat transfer power is always a linear function of the temperature gradient. Heat energy is a linear function of temperature, thus for any cooling mechanism we get a first order linear differential equation for T. In our case we assume that conduction is the dominant cooling mechanims. The solution for $r \leq r_0$ is therefore exponential:

$$T = \beta e^{-t/\tau} + T_\infty$$

for some β. Solving for $r = r_0$ and eliminating β we get the expression

$$T(r,t) = T_0 e^{-t/\tau} + T_\infty\left(1 - e^{-t/\tau}\right),\ r \le r_0. \qquad (3)$$

Heat energy is

$$Q = mc\Delta T = \sigma cV\Delta T\ ,$$

where σ is density and c is specific heat, is proportional to the product of the volume V and the temperature gradient ΔT. The heat energy lost by the ball of radius r_0 when the temperature drops to $T(r_0,t)$ is

$$E = c_1\sigma_1 \frac{4}{3}\pi r_0^2\left(T_0 - T(r_0,t)\right). \qquad (4)$$

This energy must be equal to the energy gained by the outside of this ball

$$E = c_2\sigma_2\int_{r_0}^{r} T(r,t)\frac{4\pi}{\alpha}r^2 dr = c_2\sigma_2\left(T(r_0,t) - T_\infty\right)\frac{2\pi}{\alpha}r_0(r^2 - r_0^2) + c_2\sigma_2 T_\infty\frac{4\pi}{3\alpha}(r^3 - r_0^3). \ (5)$$

Notice that the specific heat c and the density σ are not necessarily the same in (4) and (5), which is why there are sub-indices. We include them to a constant α' by defining

$$\alpha' = \frac{c_1\sigma_1}{c_2\sigma_2}\alpha$$

Setting (4) and (5) equal and simplifying gives the equation

$$\alpha' - e^{-t/\tau}\left(\frac{3}{2}\left(\frac{r}{r_0}\right)^2 - \frac{3}{2} + \alpha'\right) = \frac{T_\infty}{T_0}\left(\left(\frac{r}{r_0}\right)^3 - 1 - e^{-t/\tau}\left(\frac{3}{2}\left(\frac{r}{r_0}\right)^2 - \frac{3}{2} + \alpha'\right)\right). \qquad (6)$$

We can write it in an easier way by defining

$$x = \frac{r}{r_0},\ y = e^{t/\tau} \text{ and } z = \frac{T_0}{T\infty},$$

with these definitions (6) gives

$$y = \frac{(z-1)\left(\frac{3}{2}(x^2-1) + \alpha'\right)}{\alpha' z - x^3 + 1} \quad \text{and} \quad h = \frac{T(r,t)}{T_\infty} = \frac{\alpha' z - x^3 + 3x^2 - 2 + 2\alpha'}{3x^2 - 3 + 2\alpha'}\ . \ (7)$$

The two equations in (7) are what we need. Let us set there numbers that correspond to a hypothesis that the WTC towers were taken down by thermite. Let us set T_∞ to 290 K (17 °C). The initial high temperature T_0 should be about 3000 °C. Thus,

$$z = \frac{T_0}{T_\infty} = 11.29.$$

We want that the temperature at the distance r is high enough to ignite combustible office material. The lowest temperature that ignites wood is 180 °C, but it is quite low. Let us demand that $T(r,t)$ is about 300 °C. Setting it precisely to 307 °C gives

$$h = \frac{T(r,t)}{T_\infty} = 2,$$

so let us select $h = 2$. We would not like to have a large initial cavity. Maybe $r_0 = 2.25$ meters would be acceptable for a thermite hypothesis. Then the initial cavity has the diameter 4.5 m. Selecting a so small value for r_0 forces us to have a relatively large x. The hot footprint of each building had about 45 m radius. If conduction from the hot cavity ignites an area as large as this, r must be about 45 m. Let us set

$x = 20$.

\Now we have all terms with the exception of α', which is solved from (7) as

$$\alpha' = \frac{x^3 + 3(x^2 - 1)h - 3x^2 + 2}{z + 2 - 2h} = \frac{x^3 + 3x^2 - 4}{z - 2} = \frac{9196}{9.29} = 990\,. \quad (8)$$

The value we get for y is

$y = 5.14$.

This is fine. It gives $t = 1.64\tau$ for the time to reach this situation, but the value for α' has to be considered more carefully. The densities of granite and steel are 2.75 g/cm^3 and 8.05 g/cm^3 respectively and the specific heat constants of granite and steel are 0.79 J/gK and 0.49 J/hK respectively. Using these values we get

$\alpha = 1.82\alpha' = 1800$.

This value means that only 1/1800 part of the surface of the ball contains such steel structures, which continue long way and ignite fires in remote parts. It is difficult to say if this value is realistic without doing tests on rubble from steel framed skyscrapers.

However, assuming that it is realistic, we can conclude a bit more. Thermal conductivity of steel is about ten times that of concrete. If only 1/1800 part of the surface contains these long steel structures, then through them conducts 1/180th part of heat energy. It means that the cavity does not essentially cool because of heat that escapes through these steel structures. It cools by conduction through concrete or stone. Such conduction has $\alpha \approx 1$ and $\alpha' = \alpha$ as the material is the same. Inserting $\alpha' = 1$ to (7) gives $x \approx 1.8x_0$. It means that heat does not escape in this way further than four meters from the initial cavity. So local hot spots, if they are no the surface, would be cooled by fire brigades. Consequently most heat stays in a very small local area of the initial cavity, but rare long steel structures conduct heat, get very hot, and can ignite combustible office material even 45 m from the center of the initial cavity.

We can also notice that setting T_0 to a value that corresponds to normal office fires, 600-800 °C gives $z = 3.94$. Keeping the values $h = 2$ and $x = 20$ in (8) gives

$$\alpha' = \frac{x^3 + 3x^2 - 4}{z - 2} = \frac{9196}{1.94} = 4740\,. \quad (8)$$

This is already a very high value. It seems unlikely that normal office fires could ignite far away places in this way simply because of this value of α'. However, there is a better argument why they could not ignite far away places: it is because the normal office fires burn off before they can do so. Only some very hot spot that is not any more burning but keeps the heat because the heat is trapped in stone or concrete can ignite far away places through this mechanism.

Whether this mechanism I have described has any relevance to WTC or not, I will leave for others to decide. Theoretically it might work.

References:

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