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Pat File a Trinity

INTER-OFFICE MEMORANDUM

July 6, 1945

Smith

TO K. T. Bainbridge

FROM J. O. Hirschfelder and John Magee

SUBJECT IMPROBABILITY OF DANGER FROM ACTIVE MATERIAL FALLING FROM CLOUD

Trinity

In a previous memorandum to you dated June 16, 1945, we showed that there was the possibility of a dangerous amount of active material sedimenting down onto nearby towns, IF all of the active material were to condense onto cold sand particles with the same distribution of activity versus particle size that H. L. Anderson found in the 100 ton Trinity shot.

We have tried to examine this hypothesis in some detail. It appears likely that a considerable fraction of the active material will be co-precipitated with vaporized silica in the form of very small particles which remain suspended in the form of smoke. This smoke should gradually diffuse and cause no health hazard (unless it were washed down in a thunderstorm). Unfortunately we cannot make a quantitative estimate of what fraction of the active material will be co-precipitated in the smoke and what fraction will plate onto the cold sand. In this memo we will try to present a picture of the mechanism involved. Our present arguments would seem to indicate that the amount of active material sedimenting onto a nearby town may be less by a factor of from 2 to 10 than the amount estimated in our previous memorandum. As near as we can tell, the sand which causes the danger comes up from the crater rather than from very large distances.

I. MIXING OF ACTIVE MATERIAL WITH VAPORIZED SAND AND STEEL

Originally the active material is located in the outer fringes of the ball of fire. The ball of fire when fully expanded at the end of the one tenth of a second has a radius of around 500 feet. Because of the interaction with the ground and the reflected shock the ball of fire will be quite flat on the bottom and still almost round on top (i.e., almost a hemisphere). It will be sitting immediately on top of the crater. The crater according to present estimates will be only 190 feet in radius (see LA-292) or 60 feet according to Penney's estimates, so that all of the sand rising from the crater will pass through the ball of fire. The total amount of dirt contained in the crater as expected by MacMillan and Wilcox is 50,000 tons, or 5000 tons according to Penney. It is reasonable to expect more than 250 tons of dirt will rise into the ball of fire. The energy required to heat one gram of sand up to its boiling point (2500°C.) and vaporized it is approximately 2700 cals (This figure would apply for pure silica.) Thus the energy of 2.7 tons of T.N.T. would be required to vaporize one ton of sand. If the ball of fire contained 10% of the energy, or 500 tons T.N.T. equivalent, it could vaporize something less than 250 tons of dirt. The length of time to vaporize the sand is very short once it comes into the high temperature region. Assuming that the surface of the dirt is black and the radiation is black body, it follows that:

$$dr/dt = -2\ (T/10{,}000)^4\ \text{cm/sec}$$

Here r is the radius of a sand particle and T is the temperature of the black body. The steel tower will be dissolved at approximately one fourth this rate because of its greater density. In any case the vaporization processes are extremely rapid and should serve very effectively to cool the ball of fire down to around 5000°C.

II. CONDENSATION OF ACTIVE MATERIAL

The maximum rate at which the ball of fire could cool by emission of radiation would require 0.6 of a second to reach 2000°C. (This is calculated for a black body radiating into a vacuum.) Actually the emissivity of the ball of fire is probably somewhat greater than 0.1 which is a reasonable value for a non-luminous gas such as CO_2. Therefore a reasonable upper limit on the cooling time would be 6 seconds. At the 2000° temperature all of the solid material will presumably be condensed.

The dirt which rises when the blast wave first hits the ground is given a large horizontal velocity most of it making an angle of around 15°. This dirt has been pulverized by the blast and the upper portions are rapidly vaporized. There is no rapid method of transferring the silica vapor to the central and upper portions of the ball of fire. This process will continue until approximately 100 tons of sand is vaporized and the ball of fire is chilled below the condensation point. This silica is then rapidly precipitated in the form of a fine smoke. The upper and central portions of the ball of fire contain so little solid material that the rate of condensation is very slow. Convection currents are set up at the bottom of the ball which mix the smoke and the sand and these turbulent eddies eat into the ball of fire. The active material will adhere impartially to whatever solid it happens to hit. In this way the smoke and sand scours the 49 and fission products. The relative amount of these substances which adhere to the smoke and to the sand depends only on the relative surfaces of the two components. It is impossible for us to estimate this ratio quantitatively. If there were the same weight of silica in the form of smoke (with mean diameter of 0.5 micron) and of sand (with mean diameter of 20 microns) the smoke would have 40 times the surface and therefore pick up 40 times the active material. Actually there will be much more weight of cold sand and smoke in this mixture, possibly 4 to 40 times as much. Thus there should be 10% to 50% of the activity plated out onto the cold sand. The active material sedimenting onto a nearby town should therefore be less by a factor of from 2 to 10 than we anticipated in our previous memorandum.

The high rates of chilling make the chemical nature of the various components completely unimportant so that there will be co-precipitation of the active material with the sand in the smoke. Furthermore, 49 is known to adhere to sand and scrubbing with sand is used to remove 49 from surfaces.

At first a fraction of the fission products ($\sim$ 20%) are in the form of noble gases which transmute to alkali metals within a minute and these, of course, are easily absorbed on the smoke particles.

The large amounts of ionization in the smoke cloud will tend to prevent agglomeration and thus help to dispose the active material over a larger area. This ionization is due both to the radio activity and to the rapid chilling from the high temperatures where ions are stable.

We wish to thank Robert Kamm for his experimental assistance. He showed that Trinity sand vaporized in either a carbon arc or a tantalum crucible condenses into the form of a very fine bluish-white smoke. He also determined the distribution of particle size in normal Trinity sand which we used in our previous memorandum.

Because of the difficult nature of this problem we felt it advisable to discuss a number of the technical points with experts. Drs. F. G. Cottrell and Bernard Welch (Western Precipitation Co.) gave their opinion that the 100 micron particles about which we are concerned should sediment according to the normal Stokes' Law as we had assumed in our previous memorandum. Cement dust of the same size falls in noticeable quantities at distances up to 50 miles. Drs. Sage and Lacy of C.I.T. studied the problem of condensation of the silica and felt that practically all of it will come out in the form of smoke.

We should also acknowledge many helpful discussions with Drs. G. I. Taylor, C. S. Smith, W. G. Penney, and V. Weisskopf.

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