LAMS--933

Series A

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This document contains 6 pages.

ON THE RANGE OF ENERGY RELEASES WHICH CAN BE DETERMINED BY FIREBALL OBSERVATIONS

By

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INTRODUCTION

The problem considered here is the range of applicability of the scaling procedures[1] as applied to photographic records of the fireball for the determination of the relative yield of fission bombs.

(1) See Volume III, Scientific Director's Report of Operation Sandstone.

I - UPPER LIMIT

As to the upper limit on the yield, the method should be applicable to bombs having an energy release as high as a quarter of a million tons, a number which represents a reasonable limit on the projected yield of fission bombs. Arguments might be given which would establish a true upper limit, but this will not be done since it is, in a sense, an academic matter as to whether or not the method is applicable in the region where no bombs, at least of the fission type, will exist. It might be useful, however, to state that in the event a super bomb is developed this question should be reinvestigated, since yields much greater than a quarter of a million tons would then become possible. In passing, however, it would still seem that fireball observations might be applied even to super bombs.(2)

(2) The factors which enter into the upper limit are somewhat dependent on the height of burst. For example, a very large bomb, say a few hundred kiloton yield, burst on a 300-foot tower, would not reach the conditions of temperature and pressure corresponding to a 20-kiloton bomb burst on a tower of the same height, because of the ground reflection. If the point of detonation is instead made a few thousand feet, these limitations would no longer apply and instead one would have to be concerned with the effect of the inhomogeneity of the atmosphere. It is difficult to see how such effects could enter to an appreciable extent, even at yields as high as ten million tons. It is not felt that the effect on the ball of fire growth due to air pre-heating by neutrons and gamma rays is important to the present considerations.

II - LOWER LIMIT

The considerations which apply to the estimate of a lower limit are fortunately rendered quantitative by the existing ball of fire rate of growth data. These considerations involve the concept of scaling according to which the fireballs from two explosions are in "corresponding states" when the rates of growth are equal.

Consider Figure 1, in which is sketched the logarithm of the fireball diameter, D, versus the logarithm of the time from the instant of detonation, t, for a given bomb yield, W.[3] Since the maximum diameter at which the shock front can be readily observed coincides pretty well with the diameter at the first light minimum and is, according to the scaling laws, a function of the cube of the yield, the curve of Figure 1 is bounded by D_{max}. The fact that the log-log plot is practically a straight line over the region from about 70 meters and up is taken to indicate the validity of the similarity solution. A noticeable curvature[3] sets in at smaller diameters and may be taken to denote departure from similarity due to the effect of the finite mass of the bomb and auxiliary equipment.

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(3) See LAMS-921, Analysis of Fireball Growth at Sandstone, Figures 1, 2, and 3 for actual curves.

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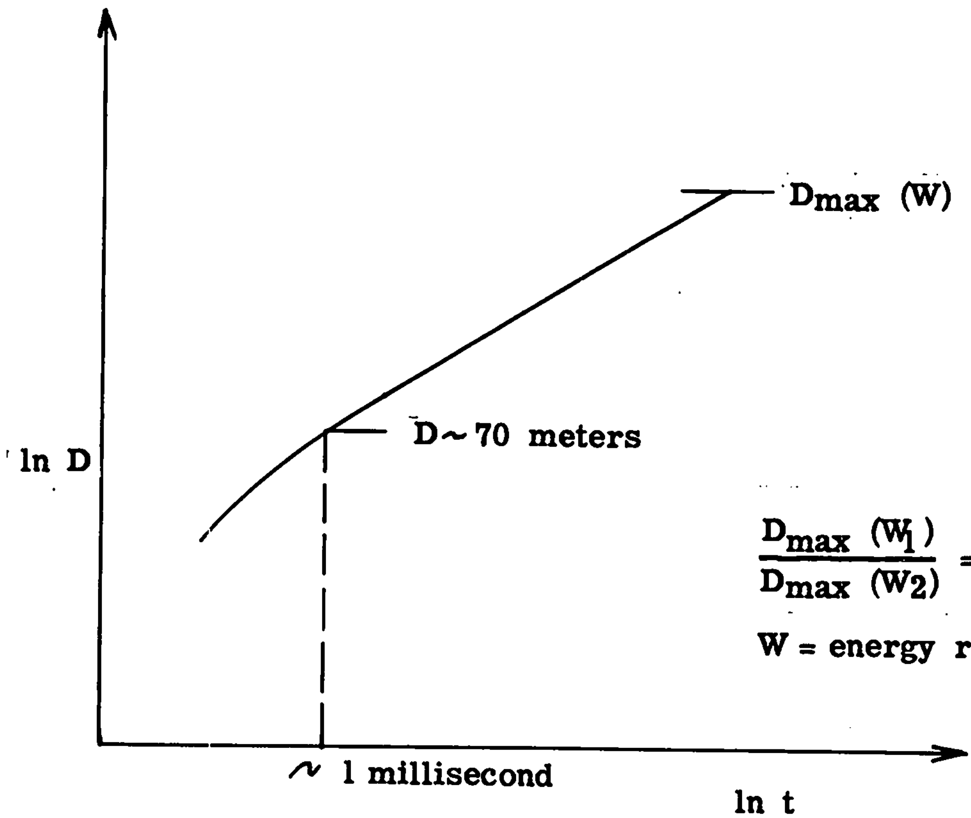

$$\frac{D_{max}\ (W_1)}{D_{max}\ (W_2)} = \left(\frac{W_1}{W_2}\right)^{1/3}$$

W = energy release

Figure 1.
FIREBALL DIAMETER vs TIME

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Having established the length of the diameter-time curve in the similarity region, it is now possible to make an estimate of the smallest yield which can be determined from photographic observation of the fireball. It is clear that, when W diminishes so far that the corresponding D_{max} becomes equal to the point at which the log-log plot begins to curve, no region of similarity remains. In order to establish the tonnage at which this happens, we simply take the cube of the ratio of D_{max} to D_{min}, recognizing that D_{min} is difficult to establish with any accuracy, and apply this factor to the observed yield for the case under consideration. From X-Ray (36.8 KT), the minimum measurable yield is found in this fashion to be 1/2 kiloton. A similar number results from the Yoke and Zebra data.

The accuracy of the method for such low yields as 500 tons is certainly poor, but should be better than order of magnitude; it improves rapidly with increasing tonnage and should be in the neighborhood of 10% at a few kilotons. It is conceivable that an improvement in observational techniques might be made in the direction of increasing the range of D_{max}, the maximum observable shock radius, and that this will enable the determination of lower yields.

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