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THE HEIGHT OF BURST OF THE GADGET

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SUMMARY

This memorandum is preliminary and the results obtained may need qualification. Information that will permit a much more reliable choice of the height of burst will reach here from Woods Hole and from England within the next two weeks. The main purpose of presenting this memorandum is to give warning that a firing height as low as 500 feet may be required. This is in contrast with earlier opinions (Waldman to Ramsey, 7 December 1944) where a bursting height 1500-2000 feet is considered. Part of the discrepancy (a factor 2.15) is due to Waldman's assuming a 10,000 ton H.E. equivalent, whereas here a 1000 ton equivalent is assumed. The remainder of the discrepancy is because here A damage is sought, whereas Waldman maximised B damage.

I. The Nature of the Target

There is a significant difference in the blast resisting characteristics of German towns and those of Japanese towns. While in Germany a broad distinction may be made between industrial buildings and the remainder, it is true that there is no pronounced contrast in the strength of one building and another, with the exception of the multi-floored reinforced concrete structures which are relatively few in number. In Tokyo and Yokohama, some areas consist entirely of extremely strong steel framed and concrete structures built to resist earthquakes, whereas other much larger areas contain only comparatively flimsy wooden houses with tiled roofs. (According to BA 424 in 1926 an area of 4400 acres in Tokyo consisted one eight by area of brick and concrete houses, one eight single storey brick buildings with wooden roofs, and three quarters wooden houses with tiled roofs. The shopping and business areas, not included in the above, consisted of steel framed earthquake resisting structures, or of relatively strong brick structures).

Therefore, it may be said that if the gadget is to be used in area attack against a German town, only one height of fusing is required for attack anywhere. Such is not the case for area attack on Tokyo. If accuracy of delivery can be guaranteed to within about 500 yards, then the bursting height for attack on wooden houses can be set twice as high as for attack on the business or shopping areas. If this accuracy cannot be guaranteed, then some suitable compromise must be worked out from tactical and statistical arguments.

I. The Nature of the Target continued

It is worth pointing out that the concentration of strong buildings into areas, surrounded by large areas of weak buildings, as found in Tokyo, is an extremely favorable circumstance for attack by the air-exploded gadget. Underneath the gadget, the very strong blast causes A damage to the strong buildings; further away the relatively weakened blast can still be enough to give A damage to the weak buildings.

II. The Type of Blast Damage to be Maximised

Once the type of structures to be attacked have been selected, the next question is "what compromise in severity of damage *vis a vis* area of damage is to be made". No such choice need be made here; we can proceed on two main alternative hypotheses.

a) The area of A damage (complete destruction) is to be maximised.
b) The area of B damage (severe but not unrepairable damage) is to be maximised.

It should however be mentioned that opinion in England has recently changed from requirement b) to requirement a). This is a major change in policy, and if a similar course is to be followed with the gadget, changes in fusing requirements may be necessary. (See later) Details are being sought from England on the current opinion of the relative values of A and B damage caused in German towns by H. E. blast, but the swing from b) to a) appears to be due to the following reasons:

1) The robot attacks on London have forced a large scale systematic repairing schedule, which has proved that "B damage" is more readily repairable than previously thought. This is confirmed by cover photographs of Hamburg and other cities showing that really large areas of B damage have been restored with incredible rapidity.

2) A damage implies many casualties, and this in turn has a very serious effect on the efficiency of fire fighting.

III. Damage Criteria: Face - On and Side - On Blast

The area of A damage from a bomb is conventially considered equal to that over which the positive hydrostatic pressure-pulse has an area exceeding 90 lbs. milliseconds per square inch. However, these are strong theoretical reasons why the criterion for much larger explosions should be changed from one of impulse to one of pressure. There is already some practical evidence that the transition region is 2-4 tons of charge (See for example BM 706). The evidence is that the area of damage observed in a model town is about the same, weight for weight of charge, for scaled down 0.6 ton, 1.2 ton and 2.4 ton charges of the same explosive. If the criterion of damage were one of peak pressure, the area of damage per unit weight of charge would be proportional to $W^{-1/3}$, where W is the weight of charge; if the criterion were one of impulse, the damage per unit weight would be proportional to $W^{1/3}$.

III. Damage Criteria: Face - On and Side - On Blast continued

The fact that the damage observed in the model town, per unit weight, was independent of the weight shows that the weights used were in the transition region. The dependence of damage per unit weight on $W^{1/3}$ is very accurately obeyed for bombs of 250 lbs. - 1 ton.

That the transition region is 2-4 tons of charge is reasonable. A blast wave in which the area pressure is a few pounds to the square inch, striking normally on a wall of a house (Face-On Blast) at first exerts double this overpressure on the wall, the extra unit arising from the sudden stopping of the air motion by the wall. Diffraction of the pulse, beginning at the top of the wall, soon relieves the pressure, which drops in a time approximately (height of wall ÷ speed of sound) to little more than the hydrostatic pressure in the blast at this time. For a wall or house 30 feet high , the time of release is about 25 milliseconds. Thus, a wall or house just able to withstand indefinitely a steady pressure of say 5 lb/in^2, can fail completely under the impact of a blast wave of overpressure 5 lb/in^2, because of the kinetic pressure of the air. Provided the duration of the blast is 25 milliseconds or more, the impulse criterion will automatically be satisfied and the failure will be determined by the pressure actually exerted on the wall. If the duration of the blast is small compared with the diffraction time 25 milliseconds, the wall may still be able to withstand the impulse given to it, and this is true however great the initial pressure so long as the impulse is less than the yield amount. Thus the region of transition from pressure to impulse is that where the blast wave have approximately the same duration as the diffraction time, and therefore corresponds with about 2 tons of charge. The above argument is certainly qualitatively correct; more exact calculations on the release of stress on the wall by inward venting of the blast into a house, and of the diffraction of the blast over the roof, are in progress.

IV. The Peak Over-Pressures to Give A, B, and C Damage

Although many experiments have been made, and much experience accumulated from enemy attacks on Britain or allied attacks on Germany, it is still not possible to say with certainty what blast pressure of very long duration will do specified damage. The following discussion may give figures accurate to within 20 per cent.

A. The radius of A damage for a 4000 lb. bomb exploding among German houses on the ground is 100 feet. (See BM 634, quoting C.I.U. (Air Ministry) figures obtained from cover photographs of 4000 lb. bomb attacks on Germany). The peak pressure at 100 feet is of the order 20 lb/in^2. This figure would certainly not apply to blast waves of long duration because:

(a) one house protects another; the blast from a 4000 lb. bomb does not immediately diffract over the top of a house;

(b) a 4000 lb. bomb is only in the transition region from impulse to peak pressure as the damage criterion; for larger explosions the peak pressure may be less.

IV... The Peak Over-Pressures to Give A, B, and C Damage continued

B. Two (2) 4000 lb. bombs air burst at 200 feet over Spezia (See Bm 634 by Christopherson) just failed to give A damage on the ground although areas of B damage were considerable. The fuses were not entirely reliable and ± 50 feet was a not unlikely error. At 200 feet from a 4000 lb. bomb burst in free air, the peak pressure is about 6.5 - 7 lb./in^2. Taking these results at their face value, 6.5 lb/in^2 is a little less than sufficient to give A damage. It must be added however that the cover photographs were poor, and the areas over which the bomb exploded were thinly covered with buildings, so that the evidence is not entirely convincing.

C. The following experiment (BM 606) gives reliable evidence that a heavy, but rather old, brick and stone structure will be destroyed by a long duration blast wave 6 lb/in^2. Pressure was created inside an old flax mill by a slow burning aluminum explosive. The building was considered to be stronger than a normal brick dwelling house, but not so strong as a brick business house or 3 storey block of flats. Pressure gauges inside the building showed pressures of 11.4 lb/in^2, and 10.5 lb/in^2 lasting at these values for 20 milliseconds. The building was wrecked (A damage) but with little to spare. The equivalent blast pressure would be half of the above pressures, because the blast doubles its pressure on striking a structure.

D. As a supplement to (C) a similar experiment in a large and strong brick and stone dwelling house (an unoccupied Scottish manse) gave pressure inside of 5 lb/in^2, and the damage was only type C (window frames, doors and ceilings).

E. The peak pressure in a blast wave which will destroy an earthquake resisting ferro-concrete structure is extremely difficult to estimate. The only information available to the writer is that a slow burning explosive placed inside a very slightly vented air-raid shelter in England was considered to produce a steady pressure of 70 lb/in^2 for at least 50 milliseconds and this was sufficient to open the walls by tearing the concrete off the steel reinforcement. Probably a pressure of 30 lb/in^2 in the blast wave would be enough to cause similar damage to the earthquake resisting buildings, but not to bring them down. The only encouraging feature for attack on these structures is that they have a natural period of vibration of rocking on the ground of 0.5 to 1 seconds, just about the period of the blast wave from the gadget (RC 263, Freeman, "Earthquake Damage and Earthquake Insurance", McGraw-Hill 1932).

IV. The Peak Over-Pressures to Give A, B, and C Damage Continued

F. To cause A damage to wooden houses, a peak pressure of 4 lb/in^2 would appear adequate, and may be an over-estimate (See report on Port Chicago where 3 lb/in^2 was accurately assessed as the B damage pressure, and Bm 711).

G. The peak pressure to cause B damage is probably about two thirds that needed to cause A damage.

H. The peak pressure for C damage may be taken uniformly as 2 lb/in^2. Only for very special reasons (e.g. gas attack, fire attack, where maximum venting is the object) would C damage be the major requirement.

Summing up, the estimated values of peak pressure to produce various types of damage in different circumstances are as follows:

TABLE I

Peak Pressure to Give	Wooden Houses	Average Brick Houses	Strong Brick Structure	"Earthquake" Structure
A damage	4	6.5	9	30
B damage	3	4.5	6	20
C damage	2	2	2	2

V. The Height of Burst to Maximise Areas Over Which Blast Pressure Is At Least P lb/in^2.

The following reports have been consulted RC. 517, 523, 557, 607, 608, 812, 862, 863, and OSRD 4076 and 4246.

The H. E. equivalent of the gadget may be defined as that weight of H.E. which gives, at the same distances, peak pressure in the range of military importance (2 - 10 lb/in^2) equal to those produced by the gadget. The energy released by the gadget may possibly equal that released by the H.E. equivalent, but may well be greater by a factor at least two, because of the relatively larger dissipative mechanisms.

From the above reports, it is possible to construct a table of heights of burst which will maximise the areas on and near the ground subjected to blast pressure greater than P lb/in^2. Table II gives the results. In order that the stem of the Mach wave should not be unduly diminished by running over buildings, it was thought that the height of the stem should not be less than three times the height of houses, and therefore the height of the stem was taken never less than 100 feet. This may be a slightly pessimistic viewpoint.

The table on the next page can be extended in scope, and the necessary calculations will be made as soon as some new data arrive from Woods Hole. What is needed is the area of each type of damage for each height of burst.

TABLE II

The Height of Burst H feet for Various H. E. Equivalents In Order to Maximise Areas On Ground Over Which Pressure is P lb/in^2 or More, and The Radius R of These areas.

Pressure P lb/in^2	Height H and Distance R Ft.	1000 tons	2000 tons	3000 tons	5000 tons	10000 tc.
2	H	1000	1300	1450	1700	2150
	R	4500	5700	6500	7700	9700
3	H	600	1050	1150	1400	1750
	R	3800	4800	5500	6500	8200
4	H	650	800	900	1100	1350
	R	2600	3300	3700	4500	5600
5	H	550	650	750	850	1100
	R	2150	2700	3100	3700	4600
6	H	440	550	650	750	950
	R	1850	2300	2700	3200	4000
7	H	340	450	500	600	750
	R	1650	2100	2400	2800	3500
9	H	250	320	350	450	550
	R	1500	1900	2150	2600	3250

VI. No Crater Will Be Produced

No direct experimental evidence is available on cratering caused by air bursts of very large charges. However, the simple scaling law that all linear dimensions are increased in the same ratio if the charge weight is increased by the cube of this ratio holds within experimental error over the range W 1/2 lb. to W 3000 lbs. Depending slightly on the nature of the soil, it is found experimentally that no crater is formed if the height of burst above the ground exceeds $W^{1/3}$, where W is in pounds. Hence, for a 10,000 ton gadget, the height is only 270 feet. Thus it appears certain that no cratering will be produced by a gadget unless it is fired to explode below 300 feet.

VII. The Possibility of Conflagration

The blitz on England caused many fires, some of them were certainly directly or indirectly produced by H. E. bombs. By far the most effective fire producer among H. E. weapons was the parachute mine. In this case, the probability of a fire certainly exceeded five per cent, and there were no complicating factors to be considered in determining the exact origin of the fire, such as fast or hot fragments. The explosion of a gadget either in Germany or Japan, causing large areas of A damage will amost certainly result in fires. While the general impression among the Fire Force in England is that the Japanes are likely to prove the most efficient fire guards in the world (because their ordinary lives gives them continual experience), the large number of casualties associated with A damage may well lead to such confusion in Japan that the critical incubation period of the fires is passed unobserved. Thereafter the fire guards are useless, and only the Fire Force counts. The possibility of eliminating a large fraction of the Fire Force of a Japanese town by getting the firemen into the radioactive contaminated area to fight fires is attractive and realistic. The success of a follow-up attack may be greatly increased in this way. For example, the "boil-over" of an oil tank in the London docks caused 1500 casualties in the personnel of the London Fire Brigade and strain put on the Brigade was one of the main reasons for Nationalizing the fire forces of Britain. A second similar incident (1200 casualties) two night later reduced the reserves absolutely to zero.

Another point perhaps worth mentioning is that the probability of a match bomb incendiary starting a fire in England or Germany is some four or five times higher if there is no fire guard interference. The incubation period during which a single person, with a little water, can easily extinguish the fire in about 20 minutes. After this, an appliance pump with hose is needed to deal with the fire. If a gadget can be followed or accompanied by small I.B.s the probability of a devasting fire, spreading well beyond the limits of the blast damage, will be greatly increased.

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