APPENDIX G

Bomb Incident-A Controlled Study

Allan Palmer, M.D.

A bomb, designated as U.S. M41 and described as an antipersonnel fragmentation bomb, exploded when it was dropped accidentally on the concrete surface of dispersal area No. 3 of AAF (Army Air Force) Station 128 at Deenethorpe, England, on 12 June 1944.[1] A mission in which aircraft B-17-G No. 42-107210 was to have taken part was cancelled. The ground crew of the B-17-G ship, together with the ground crew of another ship, were engaged in unloading the clusters of M41 bombs from the bomb racks. A shackle holding three of the bombs to one end of the support for a cluster of six was loose or broken, and during the handing down of the cluster the three bombs fell to the concrete-a distance of approximately 6 feet. One of the bombs exploded, another became armed but did not explode, and the third remained unarmed.

The official ordnance report of the accident by the ordnance officer of the Eighth Air Force is extracted as follows:

1. *Place of accident:* AAF Station 128, 401st Bombardment Group, located near Deenethorpe, England, Grid reference of field 496090.

2. *Time of accident:* 1535 hours, 12 June 1944.

3. *Bombs:* One (1) M41 Fragmentation bomb 20 lb in M1A1 cluster with AN-M110A1, instantaneous fuse.

4. *Condition of bombs:* Bombs were "safe," being unloaded from aircraft on dispersal site #3.

5. *Location of bombs:* On dispersal site #3 near buildings of the 614th Bomber Squadron Technical Supply and derelict farm house.

6. *Effects: A.* Casualties: Seventeen, of which five were killed and four seriously injured.
B. Damage: The bomb bay wing structure and landing gear of a B-17 #107210 were damaged. The aircraft is to be salvaged.

7. *Group and station to which aircraft belonged:* 401st Bomber Squadron Group (H), AAF Station 128.

8. *Events causing accident:* While unloading a cluster of 6 M41 bombs, a clasp holding bombs to carrier (adapter) evidently buckled and broke, releasing three bombs, one of which detonated on striking concrete.

9. *Action:* The loose bombs and clusters were cleared away, dangerous fuse (in one UXB) removed and destroyed. All clusters were removed from aircraft.

10. *Additional remarks: A.* To the best of our knowledge four men of Armament and Ordnance Sections of the 614th Bomber Squadron 401st Bomber Group (H) were working in each side of the bomb bay, two above and two on the ground on each side, with a number of other men standing around or helping in various ways. Usually a crew of four will load or unload a ship, but in this case men who had finished unloading other ships had come over to help finish the job on this one. Both outboard racks had been unloaded and apparently crews had begun work on the double clustered bombs on the inboard racks. It was at this time that the explosion occurred, on the left side of the bomb bay. From the information available, the double clustered bomb on the top station was being removed, although this is not certain. By later comparing lot numbers of bombs and fuses, both loose or partially clustered, it was determined with reasonable certainty from which cluster the exploded bomb came. There were three intact bombs remaining on the rear of this cluster but, the clasp attached to the strip designed to hold the three bombs to the adapter had apparently buckled and had broken, evidently releasing the three bombs which fell to the ground, one of which exploded on impact. The nose portion of the fuse on this bomb was recovered, proving that the fuse was in an unarmed condition. The adapter was of the type used to repair bombs in the U.K. and procured here. There were thus two equipment malfunctions, the broken clasp on the adapter and the AN-M110A1 nose fuse, which functioned, even though in "safe" condition.

B. One bomb from a cluster, other than the one mentioned above, fell and became armed and in a dangerous condition. The striker head and safety collar were missing from the nose of the fuse. The R.A.F. Bomb Disposal Squad at Bramcote was notified, but they stated that they were not permitted by the Air Ministry to dispose of U.S. bombs which had become dangerous during loading or unloading operations, of A/C on the ground. Consequently, the bomb was later safetied by removing and destroying the fuse.

C. The following precautions will be stressed in an effort to prevent any further accidents with this type of bomb:
During normal inspection of cluster for damage or indications of possible failure, they will be completely prepared for subsequent loading. The safety pins will be removed from the clasp and replaced with long pieces of arming wire to facili-

[1]One of the primary reasons for reporting this incident is to illustrate the type of investigation which should follow all accidents involving U.S. weapons. Under these semicontrolled circumstances, exact information can be collected in regard to (1) type of weapon; (2) number of men exposed, posture, duty, equipment and clothing, and distance from weapon; (3) number of casualties, types and severity of wounds, and extent of hospitalization; (4) recovery of fragments or bullets; and (5) documentation with photographs and X-rays. These unfortunate accidents can then be utilized as biological indicators of the effectiveness of our weapons.-J. C. B.

tate removal after loading. Safety wires are required to be in place during loading. The arming wire will be replaced with a 500 lb G.P. bomb arming wire or equivalent, and Farhnestock clips attached.

When clusters are to be unloaded, the procedure will be started from the top stations and safety wires inserted in clasps before removing bombs from racks. Although this has been required procedure, the job has been so difficult, because of inaccessibility and lack of time, that it is believed it has not been done consistently. However, this accident is considered attributable primarily to malfunctions resulting from poor equipment designs, rather than the failure to insert the safety wire. The latter procedure will serve more certainly to prevent breaking of clusters by inadvertent removal of the arming wire during handling.

D. All casualties were ground force members of the 614th Bomber Squadron 401st Bomber Group (H).

(Signed) JAMES C. DAVID,
Capt., Ord. Dept., Gp. and Sta. Ord. Officer.

SCENE OF THE INCIDENT

Within a 300-foot radius of the point of impact of the bomb that exploded (fig. 1), there were 24 men, 1 aircraft (B-17-G No. 42-107210), 1 pyramidal tent, 1 technical supply nissen hut, 1 brick farm building, and 1 bomb-carrying trailer.

FIGURE 1.-Location of men and buildings within a 300-foot radius of the point of impact of bomb.

Of the 24 men known to be present within a 300-foot radius (table 1), 6 were located just less than the full 300-foot range and were uninjured, although one of these, *S*, standing in the doorway of the brick farmhouse, was struck in the right thigh by a bomb fragment. The missile was reflected against his pocket knife and became buried in the wooden structure of the door. The man furthest from the burst who sustained injury was *L*, approximately 150 feet away. He was walking in the direction of the aircraft and was knocked down by a fragment that struck his left elbow and fractured the medial condyle of his left humerus.

TABLE 1.-*Personnel exposed to explosion of a U.S. 20-pound (M41) fragmentation bomb*

Personnel	Distance from burst	Part of body exposed	Protection	Classification	Disposition
	Feet				
A	21	Front	None	Killed	Buried
B	25	...do...	...do...	...do...	Do.
C	5	Front (above burst)	...do...	...do...	Do.
D	8	Front	...do...	...do...	Do.
E	30	Back	...do...	Died of wounds	Do.
F	23	Front	...do...	...do...	Do.
G	31	...do...	Partial, by left landing gear	Severely injured	Evacuated to Zone of Interior after 57 days.
H	28	...do...	Head protected by chin turret	...do...	Zone of Interior after 100 days.
I	32	Back	None	...do...	Returned to duty after 56 days.
J	31	Front	...do...	...do...	Returned to duty after 30 days.
K	36	Left side	Partial, by left landing gear	...do...	Returned to duty after 42 days.
L	150	Front	None	...do...	Returned to duty after 23 days.
M	6	Lower limbs (above burst)	...do...	...do...	Returned to duty after 29 days.
N	5	Lower limbs (above burst)	Partial, by inboard panel and bomb clusters	...do...	Returned to duty after 10 days
O	29	Front	Partial, by casualty F.	...do...	Returned to duty after 27 days.
P	23	Front	Partial, by casualty D.	...do...	Returned to duty after 35 days.
Q	9	Front (above burst)	Complete, by inboard panel and bomb clusters.	...do...	Returned to duty.
R	40	Front	Bomb trailer	Uninjured	Do.
S	255	...do...	Pocket knife	...do...	Do.
T,U,V,W, and X	300	Unknown	None	...do...	Do.

The remaining 17 men were within a 40-foot radius and all but one *(R)* were killed or injured. Four men were killed instantly and two died within 24 hours of the time of injury. The other casualties sustained injuries of varying severity. The least serious injury was in a casualty *(Q)* who suffered a very slight tearing of his left eardrum, resulting in a hemorrhage into the auditory canal. He was not sent to hospital but was examined and taken care of at the AAF station. This man was standing forward about 9 feet above the burst in the right bomb bay. He was protected from a direct hit by bomb fragments by the inboard panel still bearing clusters of the M41 bombs.

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FIGURE 2.-Eighth Air Force ORS battle damage report on B-17-G No. 42-107210 aircraft.

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FIGURE 3.-Damaged aircraft. A. Aircraft B-17-G No. 42-107210 of 401st Bomber Squadron Group (H). B. Bomb fragment holes in wing.

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FIGURE 3.-Continued. C. Damage to bomb bay doors. D. Damage to landing gear.

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The B-17-G aircraft was located with the men grouped about it as shown in figure 1. Damage to the aircraft is shown in the Eighth Air Force ORS (Operational Research Section) battle damage report (fig. 2) and in figure 3. The category of damage is given as "E" which, as discussed in USSTAF (U.S. Strategic Air Forces) Regulations No. 80-6, 8 May 1944, refers to an aircraft damaged beyond economical repair, such as in crashlandings.

The pyramidal tent located 150 feet to the west of the burst received no hits by bomb fragments. The brick farm building (used as a workshop) diagonally 250 to 300 feet to the southwest was struck by at least 30 high-velocity fragments having a mass estimated to be from 5 to 10 gm. Pitting of the brick wall of the building to a depth of 1 inch or more served to indicate which fragmentation marks were the result of high-velocity fragments of the estimated weight. Most of the fragmentation marks were between 4 and 5 feet above ground level. Some of the marks seemed to be due to groups of smaller fragments. These marks were clustered about a larger and deeper mark, the clusters covering an area of 25 or 30 square inches. Two large fragment marks were found approximately 12 feet above ground level and several at a height of 6 to 7 feet. One fragment made a ¼-inch hole through a piece of iron pipe, the walls of which were an eighth of an inch, and came to rest buried in a wooden door. The pipe was part of some structural framework on the side of the brick farm building, and the point at which the building was struck was exactly 252 feet from the burst, 3 feet above the ground level.

The maximum depth of the bomb crater was 1¼ inches and was located, as shown in figure 1, in the concrete dispersal area. The fragmentation pattern was assymmetrical, indicating that the bomb struck the concrete nose first but with its axis deviating from the perpendicular. The pattern radiated from the crater toward the nose of the aircraft, through an arc of 220°. At the center of the arc, the pattern extended 6 feet. Maximum extensions of the pattern, amounting to 10 feet from the crater, occurred at 55° to the right and left of the center. Here the density of strikes was greatest. At the extremities of the arc, the pattern extended no more than 3 feet from the crater, with density of strikes very slight. From these facts, it would appear that the inclination of the bomb axis from the perpendicular was in the direction of the nose of the ship, where the majority of men at work were congregated. It would appear further that the normal horizontal spray of fragments occurred to the left and right of the aircraft as indicated by the fragmentation pattern and the level and distribution of fragmentation marks on the side wall of the brick farm building. The dispersal of fragments throughout the remaining 140° of the arc not represented in the concrete fragmentation pattern appears to have been upward and slightly backward through the wings of the aircraft. The total area of wing surface hit by bomb fragments was found, by planimeter measurement on a scale drawing of the aircraft, to be 27 square feet. In this surface area, there were 180 penetrations or an average of nearly 7 strikes per square foot at distances varying from 5 to 40 feet from the burst.

It is of interest to note from the configuration of the fragmentation pattern on the concrete that with the exception of casualty *A* all the rest of the casualties on the ground were produced by bomb fragments, the velocity of which may have been considerably reduced because of the retardation produced by the richochetting of the fragments against the concrete surface.

The technical supply hut south of the burst (fig. 1) received one through-and-through, hit on the convexity of the roof structures and three hits on its front about 3 feet above ground level. The bomb-carrying trailer present at the time of the accident was not available for inspection.

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DESCRIPTION AND PERFORMANCE OF U.S. 20-POUND FRAGMENTATION BOMB

Construction

The M41 fragmentation bomb (fig. 4) has a charge-weight ratio of approximately 15 percent. Details of its construction are furnished by Prof. Marston Morse in his statement communicated to the Wound Ballistic Conference on 27 April 1944. The overall length of the bomb is 22.2 inches and its diameter about 4 inches. A long rod of square wire 0.44 x 0.44 inch is tightly wrapped about a light cylindrical casing 0.11 inch thick to form the main body of the bomb. The cylinder is filled with TNT or other explosives. The ends are sealed with steel plugs. The nose plug contains a cavity for an instantaneous fuse, and the tail plug has a threaded hole to take the tail fins.

FIGURE 4.-U.S. 20-pound (M41) fragmentation bomb.

The bomb is normally clustered into the M1A1 cluster of six bombs (fig. 5). The following loads, prescribed in USSTAF Ordnance Memorandum No. 3-54, 16 March 1944, were carried by aircraft in use by the U.S. Air Forces:

Aircraft:	*Load*[1]
B-17	38-42
B-24	52
B-26	30
B-25	30

In clusters of 6 bombs.

When an M41 bomb falls, 250 revolutions of the propellerlike blade, on the nose of the bomb, are required before the bomb is armed. This process permits the collarlike safety block located just ahead of the propeller to fall away, which in turn permits the striker head to be driven into the fuse upon impact. As stated in the official ordnance report (p. 827) and

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FIGURE 5.-M1A1 clusters of U.S. 20-pound (M41) fragmentation bombs

FIGURE 6.-Defective fuze of M41 fragmentation bomb, showing safety block in place.

as shown in figure 6, the safety block on the fuze of the bomb that exploded in the incident being reported was in place. Thus, the fuse functioned even though in a "safe" condition.

Fragmentation

The effect of wrapping the bomb cylinder with square wire is to produce a large number of fragments, each of which is a piece of rod 0.4 inch to 1 inch long (fig. 7). These fragments are much more effective per pound of metal than the usual long, narrow shell fragments.

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FIGURE 7.-Primary missiles (U.S. M41 20-pound fragmentation bomb). Fragments found in wounds of aircrew personnel killed by the accidental explosion of the 20-pound fragmentation bomb.

In static and drop trials, the number of fragments recovered is approximately 1,000 for the TNT loading and is from 40 to 60 percent greater with ednatol or RDX Compound B loadings. For the TNT loading, 75 percent of the fragments exceed 2.25 gm., 50 percent exceed 4.0 gm., and 25 percent exceed 7.0 gm. in weight. In static and drop trials at the ordnance proving grounds at Millersford, England, quoted by Zuckerman, the number of fragments heavier than 1.3 gm. was 883. Fragments of less than 1.3 gm. were not counted. Zuckerman reports the actual recovery of 319 M41 bomb fragments, weighing more than 1.3 gm. each, from the roof of the Bocca di Falco Airfield Building, Palermo, Sicily, where a single M41 bomb had burst. The total weight of the fragments was 3.65 pounds, or about 25 percent of the potential fragmenting metal. Morse gives the figure of 1,274 as being the total number of fragments weighing more than 0.25 gm. each from one M41 bomb and, for comparison with the ordnance trials at Millersford, 884 fragments weighing more than 1.3 grams.

The initial velocity of M41 bomb fragments has been reported (Eighth Air Force Ordnance Memorandum No. 3-17, 18 Sept. 1943) to be as high as 4,000-5,000 f.p.s. However, the mean velocity of fragments heavier than 1.3 gm. measured at the Millersford trials was 2,890 f.p.s. over a distance of from 0 to 10 feet, and Morse gives the average velocity at 20 feet for all fragments exceeding 0.24 gm. in weight as 2,810 f.p.s. He states further that for ednatol loading the initial velocity is 3,000 f.p.s. and for an RDX Composition B loading, 3,280 f.p.s. The Sachs-Bidelman Memorandum Report No. 267 from the Aberdeen Proving Ground follows closely if it is not actually the same as Professor Morse's statement of velocities of M41 bomb fragments for the three different loadings given.

Effective Range

Because of its cylindrical construction, the zone of maximum fragment density for an M41 bomb is extremely narrow, being approximately not more than 3° above the equatorial

plane and then only when it bursts with its axis vertical. Slight deviations of the bomb from a vertical position materially affect its effectiveness. Ordnance Memorandum No. 3-17, 18 September 1943, gives as criteria for effectiveness against personnel a minimum of two fragment hits per individual. Since a man when standing erect is regarded as presenting an average target area of 4.2 square feet, this corresponds to a minimum fragment density of approximately 0.5 fragments per square foot for effectiveness. From this, it is estimated that the effective range for an M41 bomb exploding in the vertical position is 50 feet. Approximate calculations for angles of impact at 10° and 20° from the vertical give the following figures:

Angle of impact from the vertical position (degree)	*Radius of effective range (feet)*	
	Forward	*Rear*
0	50	50
10	33	8
20	13	3

The findings at the scene of the accident suggest that the angle of impact of the bomb was at least 45°. This assumption was made because it was found that a narrow zone of maximum density of fragmentation occurred against the undersurface of the wings of the damaged aircraft at a point slightly more above than to the rear of the point of impact.

The decrease in effective range forward, for a bomb striking at an angle, obviously does not hold for a bomb falling a short distance on a concrete surface.

STUDY OF CASUALTIES

An estimate of the risk of an individual to injury by bomb fragments may be made from the data in table 1. The factors to be taken into account are as follows:

1. Surface area of the body exposed, less area protected by parts of planes, objects, or other individuals.

2. Distance from burst.

3. Direction of fragment spray.

The mean projected area of the body and its parts, as recorded by Krohn working with Burns and Zuckerman,[2] enables one to estimate the approximate surface areas of individuals exposed to injury. From these data, table 2 was compiled. It is shown that, of the seven individuals within 30 feet of the burst and without any appreciable protection, six were killed or died as a result of wounds and the seventh injured so severely that he required more than 3 months' hospitalization and was permanently lost from the service. Two individuals, *M* and *N*, within 15 feet of the burst and with only their lower extremities exposed, were out of the line of spray of effective bomb fragments and sustained only slight injuries. Two others, *O* and *P*, within 30 feet of the burst were in the line of spray but because they were almost completely protected by other individuals were only slightly injured. The four remaining individuals, *I, J, K,* and *L,* who were further distant than 30 feet from the burst and who received injuries, required hospitalization for periods averaging longer than 5 weeks. Table 3 shows the casualty rates pertaining to the 24 men known to be present at the scene of the incident.

[2]Burns, B. D., and Zuckerman, S.: The Wounding Power of Small Bomb and Shell Fragments. R. C. No. 350 of the Research and Experiments Department of the Ministry of Home Security.

TABLE 2.-*Observed hits by M41 bomb fragments sustained by casualties at various distances from burst*
["Area" refers to the approximate body surface area exposed to bomb fragments by each casualty in square feet]

Casualty	Distance (feet) from point of burst									
	0-15		15-30		30-45		150		>250	
	Hits	Area	Hits	Area	Hits	Area	Hits	Area	Hits	Area
A	---	---	19	4.2	---	---	---	---	---	---
B	---	---	15	4.2	---	---	---	---	---	---
C	44	4.2	---	---	---	---	---	---	---	---
D	10	4.2	---	---	---	---	---	---	---	---
E	---	---	8	4.2	---	---	---	---	---	---
F	---	---	18	4.2	---	---	---	---	---	---
G	---	---	---	---	2	1	---	---	---	---
H	---	---	11	3.7	---	---	---	---	---	---
I	---	---	---	---	12	4.2	---	---	---	---

J	---	---	---	---	3	4.2	---	---	---	---
K	---	---	---	---	1	1	---	---	---	---
L	---	---	---	---	---	---	1	4.2	---	---
M	10	1.65	---	---	---	---	---	---	---	---
N	4	1.65	---	---	---	---	---	---	---	---
O	---	---	3	1	---	---	---	---	---	---
P	---	---	3	1	---	---	---	---	---	---
S	---	---	---	---	---	---	---	---	1	4.2
Total	68	11.7	77	22.5	18	10.4	1	4.2	1	4.2
Observed hits per square foot surface area		5.8		3.4		1.7		0.2		0.2
Expected hits per individual when exposed area is 4.2 square feet		24		14		7		1		1

TABLE 3.-*Casualty rates of 24 men exposed to bomb fragments*

Distance from burst	Number of men exposed	Casualties (killed or wounded)	
		Number	Percent
Feet:			
0-15	5	5	100.0
15-30	7	7	100.0
30-45	5	4	83.0
>45	7	1	14.0

Figure 8 shows graphically the number of hits per square foot of body surface exposed at varying distances from the burst. These findings show a desirable distribution of fragments for antipersonnel effect and agree closely with the fragment density reported by Zuckerman in his communication from Sicily on the performance of the U.S. M41 bombs against grounded aircraft. It is of interest to note again that all of the casualties standing on the pavement toward the nose end of the aircraft, ahead of the burst, were presumably struck by fragments ricochetting on the concrete dispersal area.[3] Thus, in general, the

[3]At a later date, 28 September 1944, the writer recommended by letter, Special Incident Report, to Col. Elliott C. Cutler, MC, Chief Surgical Consultant, ETOUSA, that " * * * as a safety measure, some thought might be given by the Air Force to the loading and unloading of bombs * * * into and from aircraft on a specially prepared or selected surface."-J. C. B.

FIGURE 8.-Graphic presentation of number of hits per square foot of body surface exposed at varying distances from bomb burst.

distribution of ricochetted fragments against personnel in this incident closely approximated the distribution of fragments directly striking the wings of the aircraft damaged by the same burst. Further, the estimated fragment density at 50 feet in this incident was approximately three times as great as the estimate given in Ordnance Memorandum No. 3-17.

REGIONAL DISTRIBUTION OF WOUNDS

Table 4 shows the regional incidence of wounds in the 17 casualties. Only four individuals sustained single wounds, one of which was casualty *Q* who had only a slight tearing

TABLE 4.-*Distribution of 163 single and multiple wounds in 17 (11 wounded, 6 killed) casualties, by anatomic location*

Anatomic location	Single wound	Multiple wounds				Total wounds	
		2 regions involved	3 regions involved	4 regions involved	5 regions involved	Number	Percent
Head	2	1	3	1	5	12	7.4
Neck	---	---	1	---	3	4	2.4
Chest	1	1	6	10	29	47	28.8
Abdomen and scrotum	---	---	4	1	1	6	3.7
Upper limb	1	1	8	7	18	35	21.5
Lower limb	---	6	31	15	7	59	36.2
Total	4	9	53	34	63	163	100.0

of one eardrum. The greatest number of hits was 44, received by casualty *C* (killed). He was hit in five regions of the body including both upper and both lower limbs. This is a very conservative estimate of the number of hits since many of the wounds were so extensive that it was impossible to determine the number of bomb fragments that may have passed through the tissues.

The 28.8 percent incidence of thoracic wounds in this incident is greater than that reported in most casualty surveys of large samples and is obviously due to the inclusion of the killed with the wounded.

Table 5 shows the incidence and distribution of fractures. Four casualties sustained a total of 10 traumatic amputations of limbs or parts of limbs. These are included in the number of fractures. Of the 17 casualties, 13 sustained fractures and of these 10 had more than one.

TABLE 5.-*Distribution of 46 fractures (including amputations) in 17 casualties, by anatomic location*

Anatomic location	Number of casualties with fractures	Total number of fractures (including amputations)
Head	6	8
Chest	4	16
Abdomen	---	---
Upper limb	7	11
Lower limb	6	11

Casualty *B* (killed) presented the most extensive fracture of the skull, in addition to fractures of one upper and one lower limb. Besides comminution of the skull at the points of entrance and exit of a bomb fragment, all the bones of the skull and face, except the mandible, were disarticulated at their suture lines. The brain stem had been transected, and the entire substance of both cerebral hemispheres was macerated. The skull and brain appeared to have momentarily undergone an explosivelike expansion and cavitation. The missile stopped subcutaneously in the back of the neck after making its exit from the skull through the occipital bone.

Of the six dead, four had single or multiple penetrating wounds of the chest and one the penetrating wound of the skull described in the preceding paragraph. The sixth casualty, *D*, although he did not have a penetrating wound of the skull or other body cavities, did sustain traumatic amputations of his lower limbs in three places, multiple perforating wounds of his upper extremities, and superficial chest wounds. He presumably died almost instantly from shock and hemorrhage. His eardrums were intact.

The only evidence of damage by blast was the slight tearing of an eardrum in casualty Q who was within 10 feet of the burst but completely protected from a direct hit by the intervening inboard panel and clusters of bomb still in place. The eardrums of others, closer to the burst, were intact.

SIZE OF FRAGMENTS CAUSING WOUNDS

The sizes of fragments responsible for wounds were determined by weighing those recovered from the dead and estimating the weights of others from their X-ray silhouettes. In the case of the latter, the fragments were estimated in grams from their linear dimensions. A large series of X-rays of fragments of known weight were available as a standard. Table 6 summarizes the information obtained on this point and also gives the distances from the burst at which the casualties were struck.

TABLE 6.-*Size of fragments recovered from casualties struck at several distances from point of burst*

Category of casualty and distance (feet) from point of burst	Number of casualties	Fragment size (grams)					Total number of fragments
		0.001 to 0.05	0.05 to 0.25	0.25 to 1.0	1 to 5	>5	
Wounded:							
0-15	1	6	---	2	---	---	8
15-30	3	2	7	6	1	---	16
30-45	3	---	6	9	1	---	16
Total	7	8	13	17	2	---	40
Killed:							
0-15	1	---	1	2	---	---	3
15-30	4	---	2	1	7	1	11

Total	5	---	3	3	7	1	14

In all, there were 40 bomb fragments in 7 of the wounded that could be seen in X-ray films and 14 fragments recovered from 5 of the killed casualties. This represents a recovery of 90 percent of fragments causing wounds in the living but only 13.4 percent of fragments causing wounds in the dead.

The average weight of fragments causing wounds in the living casualties was 0.43±0.65 gm., whereas the average weight of fragments recovered from the dead was 1.86±1.82 gm. The difference in mean weight of fragments causing wounds in the killed and in the wounded in this incident involving a small number of people was found to be 1.43±0.48 gm. *(t*=2.98, *P* less than 0.01). The difference in the mean weights is statistically significant. It may be assumed that the mean weight of fragments causing wounds in the dead is considerably greater than shown in the sample, since, by far, the majority of them caused through-and-through wounds and were not retained or recovered. On the other hand, the X-rays of fragments in the wounded that were available for study represent practically all of the fragments responsible for the wounds in the living. From the average fragment weight found in the X-rays of the living casualties, it may be said that M41 bomb fragments of less than 1 gm. in weight are relatively incapable of producing fatal injuries but are definitely incapacitating in their effect.

Bomb fragmentation trials in which the screens have failed to recover fragments weighing less than one twenty-fifth of an ounce lack ballistic data on fragments of such small size. However, the wounding power of small fragments has been discussed at great length by Burns and Zuckerman. Their conclusion that within the 100-foot radius of a bomb burst 50 percent of the wounding power of a 20-pound fragmentation bomb is due to fragments weighing less than one twenty-fifth of an ounce is well supported by the findings in this incident.

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