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OPERATION HURRICANE GROUP REPORTS

(PART 40)

The Penetration of the Gamma Flash into Anderson Shelters and Concrete Cubicles

G. R. Stanbury
(Scientific Advisers' Branch, Home Office)

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ATOMIC WEAPONS RESEARCH ESTABLISHMENT

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Received on 23rd March, 1954.

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1. Introduction [redacted]

Anderson shelters were designed to protect people against the effects of HE blast. Atomic warfare calls for a design of shelter which will not only provide a given standard of protection against blast, but will provide the same standard of protection against the other effects of an atomic explosion, and in particular the gamma flash. Thus, besides assessing the damage produced on Anderson shelters by the blast, it was necessary to measure the gamma flash dose inside so that the two risks could be accurately compared. Incidentally, the protection afforded by an Anderson shelter against gamma rays is extremely difficult to calculate owing to its irregular shape and the only satisfactory way of assessing its value in this report is to measure it.

The concrete cubicles were erected primarily to study the effect of atomic blast on large reinforced concrete panels; they were not intended as models of shelters. Nevertheless their regular shape, and especially the range of thicknesses available at T.C.11 made them invaluable for studying the penetration of gamma rays through thick shields and comparing the results obtained with those calculated by the method of Liston and Cave - High Explosives Research Report No. H13/51 - "Tables for the Solution of Gamma-Ray Shielding Problems".

2. Procedure

2.1 Anderson Shelters

At each of five sites T.C.1:2:3:4 and 5, three Anderson shelters were erected, one having its opening facing the explosion, one sideways on to the explosion, and one with its opening facing away from the explosion; for short they were known as FRONT, SIDE and REAR. The average effect of an explosion is then obtained approximately by taking the average of the effects of FRONT + 2 SIDES + REAR.

In addition to the possible variation from front to back in the shelter, there was also likely to be a variation vertically, since below ground level there was more protection against gamma rays than above. The measurements were therefore made at the four positions a, b, c and d shown in Figure 1.

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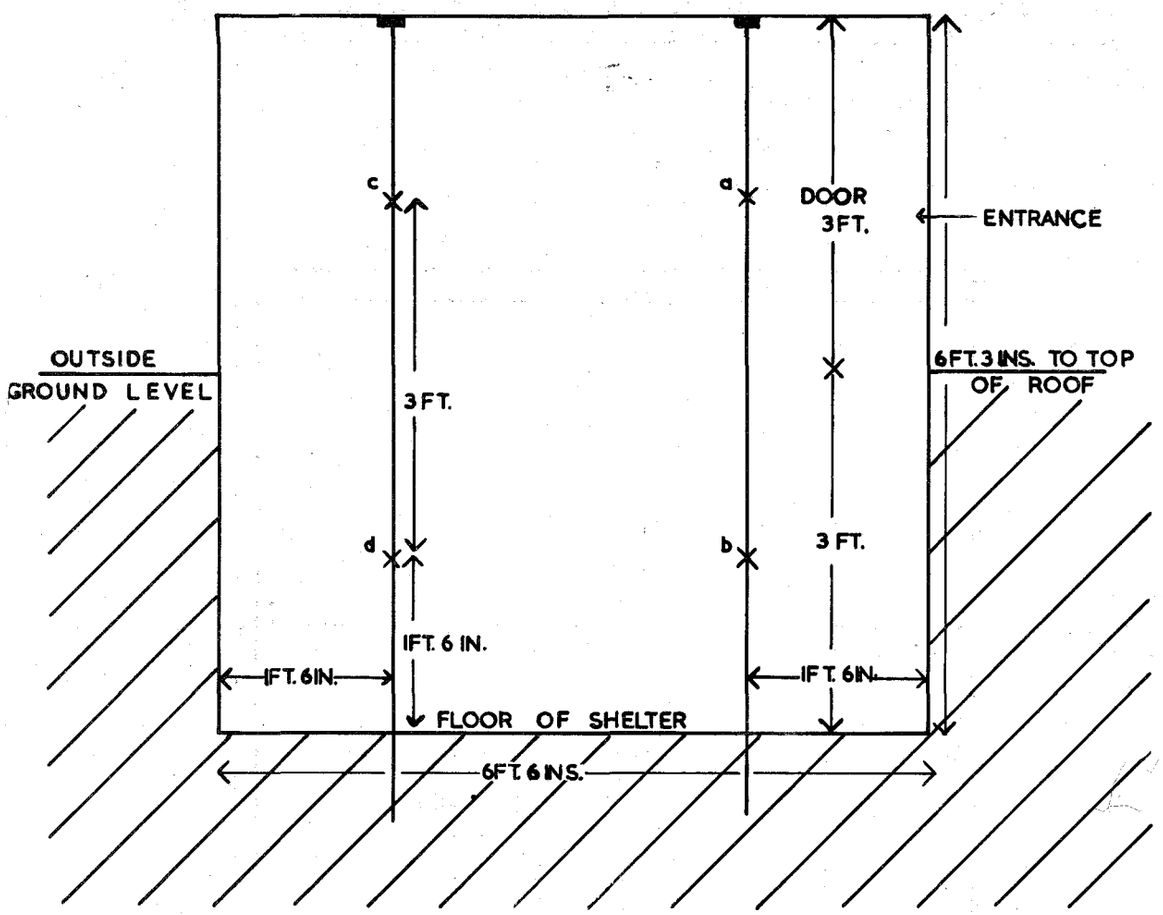
Figure 1



Strong wires were suspended from two of the holding bolts in the roof and wedged in the sand of the shelter floor. At points a, b, c and d there were strong hooks which could be stuck through the plastic covering of the film badge, to make strong supports. This is shown in Photographs No. 89 and 90.

The film badges were supplied by the R.H.2 team and placed in position by them on 27th September (D - 6). It was considered that in the shade of the shelters the film badges would suffer no deterioration in this short time.

2.2 Concrete Cubicles

These cubicles were 12 ft. cube on the inside, the thickness being as follows:-

T.C.10 $9\frac{3}{4}$ in.
T.C.11 $6\frac{3}{4}$ in., $9\frac{3}{4}$ in. and 12 in.
T.C.12 $9\frac{3}{4}$ in.

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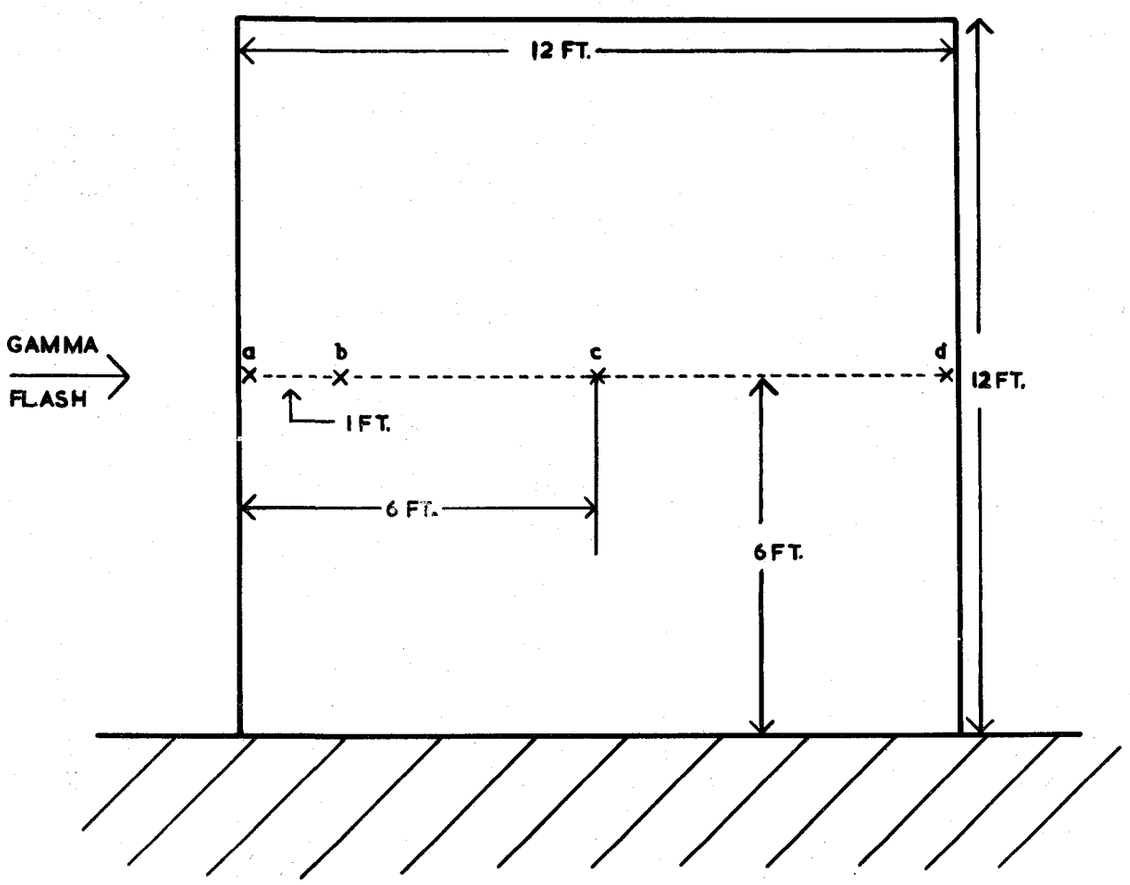
All of the front faces were normal to the direction of arrival of the flash and to all intents and purposes were on the same horizontal level. This greatly facilitated the computation of the dose inside by the method of Liston and Cave (loc. cit.).

Film badges were placed at four positions, a, b, c and d, across the shelter as shown in Figure 2. at a height of 6 ft. above the ground, and along a central line, and this enabled the computational method to be compared with the actual results at each of these positions.

Figure 2



Wires were strung across from side to side to clips which had been left on the inside of the concrete during erection, and the plastic coverings of the film badges were hooked on to these at the appropriate points.

The badges were all supplied by R.H.2 team and placed in position by them on 27th September (D - 6).

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3. Results

Some of the film badges were recovered four days after the explosion and the remainder seven days after.

At T.C.1, T.C.2 and T.C.3 damage was so severe that some of the badges could not be found. Those that were recovered were usually embedded in the sand on the floor but were still attached to the wire, and once the latter could be found, the badges could be dragged out of the sand.

The results obtained from the recovered badges are given in Tables 1 and 2.

The badge on the front wall of the $9\frac{3}{4}$ in. cubicle at T.C.11 was found on the floor and it is not possible to say whether this happened before or after the explosion. The result for this badge is certainly inconsistent with the remainder in this group and is probably not valid.

At T.C.10 the front wall of the cubicle was pushed in, and the major part of it found leaning against the back wall as shown in Photographs No. 19, 20, 22 and 23 in the damage report on these cubicles. However the top of the broken section was still about 9 in. below the halfway line of the back wall, and the film badge on the latter was fully exposed and easily recoverable by scrambling up the sloping concrete. In order to recover the remainder it was necessary to crawl round the edge of the pushed-in wall and scrape underneath. Since these badges were not fully protected for the whole period of emission of the gamma flash they would be likely to read high, especially "d" the one on the back wall - which was fully exposed as soon as the front wall collapsed; moreover this particular badge remained exposed to the full effects of residual contamination for 7 days.

3.1 Anderson Shelters

3.1.1 Discussion of Results

Even when erected strictly according to specification it is not an easy matter to calculate the degree of penetration of gamma radiation into an Anderson shelter owing to its irregular shape. In this trial further irregularities were introduced in the actual erection because various working parties were used from time to time and there was a natural, though unscientific desire on the part of some of them to make the shelter as good as possible instead of as close to specification as possible. Despite this, the consistency of erection was generally good.

The density of the filled sandbags used for covering was about 100 lb./cu.ft. which was 75 per cent of that of the concrete used in the cubicles. The physical damage to the shelter from the blast is reported on separately.

T.C.1. Only one usable film badge was recovered from this site, and this showed a below ground level lethal dose of over 10,000 r.

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T.C.2. The inside doses here also would have caused the death of all the occupants.
For each shelter in this group the equivalent concrete protection above ground level in any direction against horizontal radiation was about 30 in. for which the attenuation factor for 4.5 Mev gammas should be 0.01 (Table 7.37 "Effects of Atomic Weapons"). The measured penetration was more than an order greater than this (0.23 above, 0.12 below). It is possible that a large amount of radiation found its way through the entrance despite the presence of the blast wall; e.g. in the case of the REAR shelter where the entrance was protected by the whole of the shelter and not just the blast wall, the dose below ground level was only 1/5th of that in the FRONT shelter. Moreover it is understood that although 80 per cent of the gamma radiation was emitted in the first second, the cloud had already risen to 1800 ft. by that time. This meant that some of the radiation entered the shelter through the roof where the protective covering was less than at the sides, being equivalent to less than 1 ft. of concrete. It is obvious, however, that it cannot have been a very high proportion otherwise there would not have been such a pronounced difference between the above and below ground figures, while if all the radiation had arrived horizontally or below we should have expected a greater difference than was actually found. It seems fair to infer that an appreciable proportion of gamma radiation arrived from an angle above the horizontal, and that a large part of the dose inside was made up of radiation finding its way in directly through the entrance.

T.C.3. A more complete set of film badges was recovered from this site and they showed again that the inside doses were lethal.
The FRONT shelter showed more clearly that variation from front to back (i.e. comparing "a" with "c" or "b" with "d") which would be expected if radiation had come through the entrance as well as the protective covering.

There seems no very sound explanation of the one very low value in the REAR shelter: the blast wall here was rather longer and thicker than most of the others and this undoubtedly contributed to a reduction of the radiation coming through the entrance.

T.C.4. The attenuation was much greater here than at T.C.2 or T.C.3 being about 0.038 above ground and 0.025 below; fatal casualties from the gamma flash would have been unlikely at this range. This low penetration may be explained by the fact that at this distance the mean angle of arrival of the rays was somewhat less than at the nearer positions so that less of the dose was received through the roof and the entrance.

The particularly low value in the SIDE shelter may be partly explained by the fact that the sideways protection facing the explosion consisted partly of bull-dozed sand, giving an equivalent thickness of concrete of about 4 ft. 6 in.

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T.C.5. The attenuation here was still greater than at T.C.4, and the doses inside so low that they would be unlikely to produce any invalidity in the occupants.

3.1.2 Conclusion

The change in effect from T.C.3 to T.C.4 was rather too large and from the point of view of gamma ray penetration it would have been better not to have had T.C.1 but an additional site between T.C.3 and T.C.4.

It may be concluded, however, that for a burst of this nature, an Anderson shelter will provide complete protection against death from gamma radiation beyond $\frac{1}{2}$ mile. The advantage of getting down on the floor below ground level is very marked.

For an air burst where more of the radiation would arrive through the roof and entrance, this result would not necessarily apply,

The results emphasise the importance of providing a good long blast wall as close as practicable to the entrance or of siting the entrance towards a building so as to provide protection from that direction.

3.2 Concrete Cubicles

Nothing much can be made of the readings from T.C.10 owing to the collapse of the front wall and the consequent exposure of the film badges inside to some radiation which did not pass through the concrete. This exposure occurred not only during the explosion, but also subsequently from the ground contamination.

The readings at T.C.11 are more illuminating.

By comparing the measured attenuation factors with those calculated by Liston and Cave's method for different gamma ray energies, it seems that the average energy* of the radiation outside must have been about 1 Mev whereas for ranges beyond 3,000 ft. the U.S. book "The Effects of Atomic Weapons" gives a value of 3 Mev. The variation in dose across the shelter was generally in line with that calculated by Liston and Cave's method.

If we combine the three sets of attenuation factors, they give a general factor of about $e^{-\frac{s}{4}}$ where s is the thickness of concrete in inches. The factor pr[redacted] on the advice of A.E.R.E. - based presumably on a 3 Mev average energy [redacted]s exp (- s/6.75). This means that for the thickness of concrete as used in this trial we have been over-estimating the dose inside shelters by a factor of about $2\frac{1}{2}$, and whereas previously the death rate behind 1 ft. of concrete at 3000 ft. was assumed to be 50 per cent it is now seen to be much nearer 5 per cent and all previous estimations of casualties have been much too high.

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*This average energy has been more recently and correctly described by Lax as the energy of the equivalent homogeneous radiation, i.e. that radiation which being mono-energetic and mono-directional would produce the same results as were, in fact, produced by the actual radiation.

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Other factors may modify this conclusion to some slight extent, the foremost of which is the rise of the radioactive cloud already mentioned in connection with the Anderson shelters. It is now understood that 50 per cent of the gamma radiation was received in 0.1 sec. by which time the fireball had risen to 900 ft., and 80 per cent was received in 1 sec. when the height was 1800 ft. the whole of the dose was received within 1 min. This is equivalent to an increase in the thickness of the cubicle wall of about 15 per cent and this would have the effect of increasing the values of average energy deduced in Table 2 by a small amount. However it cannot be too strongly emphasised that the average energy recorded in this Table has no real physical significance and is only that value of the energy which, when used with Liston and Cave's method, gives the correct answer. Since the fireball must necessarily rise, it is evident that the attenuations as given in Table 2 are those which will actually apply in practice so that the values of average energy quoted are still those which should be used in calculations based on Liston and Cave's method.

Another factor which may have influenced the result was the fact that some of the initial high energy radiation may have been absorbed in the cloud of vapourised metal, water etc; this would not have happened with an air burst bomb.

Finally it should be noted that normal incidence is the worst possible case. For any other angle of incidence the dose inside would have been lower than that actually measured.

4. Conclusions

The results are consistent with the assumption that for this type of explosion the average energy of the gamma flash outside was about 1 Mev.

They indicate that complete protection against the lethal effects of the gamma flash (i.e. a dose between 100 to 150) could have been obtained inside a 12 in. thick reinforced shelter beyond a distance of about 1100 yd. from a nominal weapon.

Previously it has been the custom to use a figure of 3 Mev for calculations on air burst bombs and this would have led to a dose inside the cubicles $2\frac{1}{2}$ times higher than that actually measured.

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Table 1

Anderson Shelters

Site	Dose Outside (r)	Details of Dose Inside				Estimated Average Dose (r)	Attenuation Factor	Remarks
		Elevation Facing T.V.	Position of Badge	Number of Badge	Dose (r)			
T.C.1	75,000	Front	a	425	N.R.	Below Ground Level: 10,500	0.14	N.R. indicates film badge not recovered. These shelters were almost completely blown apart and only one badge was recovered in a serviceable condition.
			b	6	"			
			c	7	"			
			d	8	"			
		Side	a	9	"			
			b	430	"			
			c	1	"			
			d	2	10,500			
		Rear	a	3	N.R.			
			b	4	"			
			c	5	"			
			d	6	"			
T.C.2	47,000	Front	a	7	11,000	Above Ground Level: 11,000	0.23	Blast damage was not quite so complete as at T.C.1, and 8 film badges were recovered.
			b	8	N.R.			
			c	9	10,000			
			d	440	>8,800			
		Side	a	1	12,000			
			b	2	N.R.			
			c	3	10,300	Below Ground Level: 5,500	0.12	
			d	4	4,600			
		Rear	a	5	N.R.			
			b	6	"			
			c	7	11,200			
			d	8	2,100			
T.C.3	30,000	Front	a	9	7,600	Above Ground Level: 7,000	0.23	Although severely damaged the main structure of the shelters still remained intact.
			b	450	3,325			
			c	1	5,600			
			d	2	2,300			
		Side	a	3	7,400			
			b	4	2,200			
			c	5	7,000	Below Ground Level: 2,000	0.067	With this shelter the blast wall was 2'6" longer than normal and the entrance was better protected against scattered radiation. Hence the low value at (d)?
			d	6	2,200			
		Rear	a	7	N.R.			
			b	8	"			
			c	9	"			
			d	460	405			
T.C.4	4,000	Front	a	1	215	Above Ground Level: 150	0.038	Damage was confined mainly to removal of sand bags and distortion of blast walls.
			b	2	224			
			c	3	118			
			d	4	112			
		Side	a	5	145			
			b	6	55			This shelter had additional side protection of bull-dozed sand, giving a total equivalent thickness of concrete of 4'6". Hence the low values, especially below ground.
			c	7	N.R.	Below Ground Level: 100	0.025	
			d	8	31			
		Rear	a	9	225			
			b	470	N.R.			
			c	1	260			
			d	2	200			
T.C.5	1,200	Front	a	3	40	Above Ground Level: 30	0.025	These shelters were practically undamaged by blast.
			b	4	17			
			c	5	20			
			d	6	27			
		Side	a	7	38			
			b	8	14			
			c	9	38			
			d	480	10			
		Rear	a	1	26			
			b	2	13			
			c	3	10			
			d	4	6			

Table 2

Concrete Cubicles

Site	Dose Outside (r)	Details of Dose Inside				Actual Attenuation Factor	Theoretical Attenuation Factor for*				Estimated Average Energy (Mev)	Estimated Average Dose (r)	Estimated Average Attenuation Factor	Remarks
		Thickness of Cubicle	Position of Badge	Number of Badge	Dose (r)		3 Mev	2 Mev	1 Mev	0.5 Mev				
T.C.10	30,000	9¾ in.	a b c d	485 486 487 488	3,575 2,400 2,000 3,875									The front of this cubicle was blown and some gamma radiation penetrated inside. Gauge d was exposed to the open after the collapse of the panel.
T.C.11	2,800	6¾ in.	a b c d	489 490 491 492	455 545 410 430	.16 .20 .15 .15	.45 .45 .43 .39	.37 .37 .34 .30	.23 .23 .21 .17	.14 .14 .12 .083	Slightly < /	450	.16	
		9¾ in.	a b c d	493 494 495 496	128* 322 260 230	.12 .093 .082	.29 .29 .28 .25	.21 .21 .19 .17	.11 .11 .10 .077	.050 .050 .045 .027	About 1	270	.096	*This film badge was found on the ground. The reading is not consistent with the remainder.
		12 in.	a b c d	497 498 499 500	220 195 185 158	.079 .070 .066 .057	.21 .21 .20 .18	.14 .14 .13 .11	.059 .059 .052 .042	.022 .022 .020 .012	Slightly > /	180	.064	
T.C.12	380	9½ in.	a b c d	501 502 503 504	62 58 35 46	.16 .15 .092 .12	.29 .29 .28 .25	.21 .21 .19 .17	.11 .11 .10 .077	.050 .050 .045 .027	Between 1 and 2	45	.12	

*Calculated for normal incidence on Front Wall according to M.O.S. Report No. H 13/51.

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Photograph No. 89 Ref. F. 1161

Method of mounting film badges inside Anderson Shelters.

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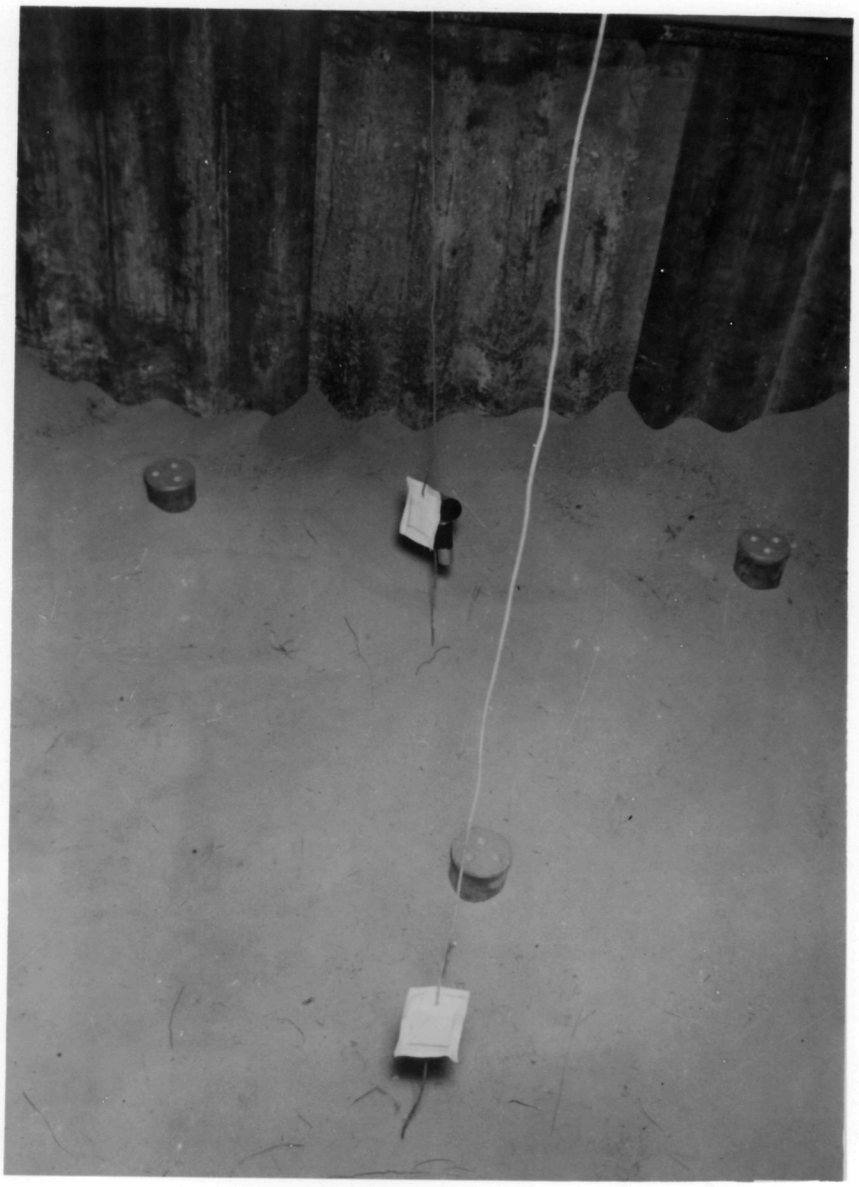
Photograph No. 90 Ref. F. 1164



Method of mounting film badges inside Anderson Shelters.

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