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8 Apr 2026

14/12/57

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TOP SECRET — ATOMIC.

Reference: NSP/P/10.
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The hazards arising in an incident involving a fully assembled Green Grass warhead.

This paper specifies the major hazards arising as a result of the accidental detonation of the H.E. component of a Green Grass warhead. Each hazard is considered separately, and steps are recommended to minimise the effects of such an incident.

To ensure that no fissile yield will result from an accidental detonation of Green Grass, under all conditions of storage and transport [redacted] mbly. [redacted] out by S.N.P. and S.N.R. respectively.

Thus the incident considered in this paper is an accidental [redacted] oading [redacted] This is a realistic problem as conditions liable to result in the detonation of the H.E. component can easily be envisaged.

The specific activity of U 235 is approximately 100 times that of natural uranium. [redacted] Therefore in any assessment of the radiological hazards arising, the presence of the natural uranium may be neglected.

Neglecting the direct effect of blast damage, etc., resulting from the detonation of the H.E., two other possible hazards must be considered. These are as follows:—

(1). The possibility of a situation arising in which U 235 debris is inadvertently brought into a supercritical assembly. This may arise in three conceivable ways:—

(a). The U 235 component of the warhead being directly scattered in such a manner as to assemble a supercritical mass.

(b). The scattered U 235 debris being 'washed' into a super-critical assembly by the indiscriminate use of liquid fire-extinguishing materials.

(c). The U 235 debris being collected into a super-critical assembly during subsequent recovery action.

(2). The radiological hazard to humans and grazing animals resulting from the inhalation and/or ingestion of uranium particles from the cloud arising from the incident.

These two main hazards are now considered separately.

/(1) Criticality hazards.

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(2) Criticality Hazards.

S.W.P. has stated that in his opinion less than 10% of the uranium in the warhead will actually be carried up in the cloud. One must therefore assume that approximately 90% i.e. 59 Kgs., of the U 235 will be scattered around the centre of the incident in the form of 'lumps' of various sizes.

In Green Grass, [redacted] weighing approximately 3 Kgs. It is therefore inconceivable that pieces larger than 3 Kgs. will be scattered as a result of an incident.

No exact knowledge of the nature of the scattered debris can be obtained from any minor trials so far completed for the following reasons:---

(a). Most of the firings involved the use of [redacted] components.

(b). All firings involved [redacted].

(c). All assessments of the spread of R.A. material were made on materials such as polonium, which are much more volatile than uranium.

(d). Deliberate attempts were made to ensure that as high a fraction as possible of the R.A. material is carried up in the cloud.

If it is therefore assumed that the U 235 is scattered randomly [redacted], it is evident that no direct criticality hazard will arise. Under highly improbable conditions of recovery, it might be possible to assemble a super-critical mass. Therefore before any recovery is attempted, trained staff will have to determine the position of all major pieces of U 235, and the recovery programme planned accordingly.

The second problem is that of fire-fighting. This problem is accentuated by the following factors:---

(a). Uranium is a very difficult material to extinguish once it is ignited. Common fire-fighting materials such as water, carbon dioxide foam and carbon tetra-chloride, are of little use. The only acceptable materials are Pyromet (which consists largely of sodium chloride) and sand. It is therefore recommended that these materials be used to extinguish any uranium fire. No criticality hazard will arise from the use of these materials.

(b). Only water is a really effective extinguisher for use with burning H.E. As the use of water may possibly lead to a criticality hazard, it is felt that no attempt should be made to fight an H.E. fire.

(c). Should a fire arise in a transport vehicle, other than in the assembled warhead, provided that the warhead is not directly involved in the fire-fighting action, the escort must use his discretion as to the use of foam extinguishers, etc.

(2) Radiological hazards.

The radiological hazards arising from such an incident may be divided into two main classes:---

---2--- /(a) the inhalation

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(a). The inhalation hazard to humans.

(b). The ingestion hazard to grazing animals, and thus the indirect hazard to humans due to consumption of contaminated food such as meat or milk.

U 235 has a specific activity of approximately 68 millicuries per Kilogram. Green Grass therefore contains approximately 4½ curies of uranium. If, as suggested earlier, a maximum of 10% of the total activity is taken up in the cloud, we may assume that 0.5 curies of activity are distributed throughout the cloud.

The maximum permissible total body burdens for uranium in humans as quoted by the I.C.R.P. are as follows

Table 1.	Critical Organ.	M.P.T.B.B.
Uranium(soluble).	Kidney.	0.04 micro-curies.
Uranium(insoluble).	Lungs.	0.01 micro-curies.

The following distribution for inhaled uranium particles is also quoted from the I.C.R.P.

Table 11.

Total quantity inhaled.	Immediately exhaled.	Trapped in upper respiratory tract.	Trapped in lower respiratory tract.
100%.	25%.	50%.	25%.

The 50% in the upper respiratory tract is almost immediately swallowed whilst ½ of the uranium in the lower respiratory tract, i.e.12½% of the total intake is expelled and subsequently swallowed in the first 24 hours. Therefore the effective retention by the body is

Lungs.	12½%.
G.I. tract.	62½%.

The uranium particles arising from such an incident as is being considered will be either finely divided metal or U_3O_8. These are almost completely insoluble, and will therefore pass quite rapidly through the G.I. tract without absorption. Thus the major hazard arising from the incident is from uranium trapped in the lungs, which has a biological half-life of 120 days.

The maximum permissible total body burden is calculated so that the dose rate to the critical organ does not exceed 0.3 rem/week. This implies that the critical organ will receive from 1 body burden an integrated dose of approximately 7½ rem. For trials work, it has been agreed that a single dose of 25 rem. to the critical organ can be accepted. Thus the effective body burden for a single incident may be increased by a factor of at least 3½ over that quoted in Table 1.

Combining the above factors, one therefore calculates that the maximum amount that may be inhaled to give a 'hazard body burden' is

$$\frac{0.01 \times 3\frac{1}{2}}{0.125} \text{ micro-curies} = 0.4 \text{ micro-curies.}$$

To estimate the amount of R.A. material inhaled from the cloud, a method suggested by Martin, S.S.H.P., has been used.

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Results obtained at Foulness for firings involving Green Grass scale charges under average meteorological conditions are given below in Table III.

Table III.

Time after Initation.	Round 11. Height of centre of cloud.	Round 11. Depth of cloud.	Round 12. Height of centre of cloud.	Round 12. Depth of cloud.
0.3 sec.	47 ft.	50 ft.		
1.0	65.	96.		
2.0	81.	126.		
3.0	90.	148.		
4.0	104.	217.		
5.0	125.	262.	154 ft.	220 ft.
6.0	140.	275.	163.	250.
7.0	177.	282.	173.	270.
8.0	189.	311.	180.	284.
9.0	205.	324.	191.	296.
10.0	229.	340.	200.	327.

These results indicate that the cloud leaves the ground very rapidly, and therefore no inhalation hazard can exist for long after initiation.

The cloud reaches a roughly hemispherical form, of radius approx-imately 50 ft., within less than 0.3 second of the instant of detonation. Hence the average contamination in the cloud is approximately 7×10^{-5} microcuries/ c.c. Therefore to inhale 0.4 microcuries, a person may inhale 6000 c.c. Taking the I.C.R.P. breathing rate of 10^{7} c.c./ 8 hr. working day, and a person may therefore breath the cloud for approximately 20 seconds. As is shown by Table III, it is impossible to breath the cloud for this period, and therefore no inhalation hazard will arise while the cloud is ascending.

Under adverse meteorological conditions, it is possible for the cloud to remain in contact with the ground. Martin quotes a case such as this; this firing occurred in a wind of approximately 30 knots. Thus even shortly after the instant of detonation, when the cloud has a diameter of approximately 100 ft., the cloud will pass a person in 2 seconds. It is therefore inconceivable that even under these conditions that an inhalation hazard will arise.

It is still possible, of course, that an inhalation hazard will arise when the cloud descends. The Foulness results indicate that when the cloud heights stabilise, the cloud occupies a volume of approximately 7×10^{13} c.c. Thus the average contamination in the cloud will be approximately 10^{-8} microcuries/ c.c.

If it is assumed that the cloud descends without further diffusion, the cloud could be breathed for approximately 36 hrs. without a hazard body burden being retained. It is therefore again impossible for the cloud to present any inhalation hazard to humans.

The ingestion hazard to grazing animals will arise from the settling

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of the cloud on an area determined by wind velocities, etc.

Dean (HP memo 5/56) has estimated that cattle can tolerate up to 10 microcuries/ day of uranium. The average area grazed by cattle per day is 250 sq. metres, and this therefore implies that a contamination of 0.04 microcuries/ sq. metre will represent a hazard to cattle.

Since a total of ½ curie of uranium is assumed to be taken up in the cloud, it is therefore possible that a hazard to cattle will exist over an area of approximately 10^7 square metres. If this area consists of a segment of a circle of total angle 10^0, this implies that a hazard may exist to cattle at distances up to 20 miles downwind. This, of course, is an upper limit to the distance in which a hazard will arise. It is highly improbable that a hazard will exist out to this distance.

The hazard to cattle will be augmented if there is the possibility of the ingested activity being passed on to humans by consumption of contaminated meat or milk. If the uranium is again assumed to be insoluble, it is extremely unlikely that any appreciable amount of uranium will transfer into the animal tissues or milk within a period of days. If therefore, efficient control is set up over the contaminated area within 24 hours, no hazard will arise to humans as a result of ingestion of uranium by cattle.

Summary.

(1) No inhalation hazard to humans will arise from an incident.

(2) Only Pyromet or sand should be used for fire-fighting.

(3) A trained escort team, accompanying the transport vehicle at a safe distance will enable the following controls to be established with the aid of local constabulary.

(a) Immediate control of the vicinity until the distribution of the U 235 has been determined.

(b) Control of any fire-fighting action, ensuring particularly that no water is used on the debris.

(c) Control over the area which, after survey, appears to present a hazard to grazing animals.

(4) Given the above escort team, no direct or indirect radiological hazard to humans should result from an incident involving Green Grass.

December 14th, 1957.

Distribution.

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