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THE HAZARDS ARISING FROM THE ACCIDENTAL DETONATION OF THE H.E. COMPONENT OF A WARHEAD CONTAINING U238 AND/OR U235.

This paper has been prepared at the request of the Nuclear Safety Panel. Most of the relevant data has been obtained from papers supplied by Mr. Hicks, S.W.P., who has also helped considerably by discussing this problem with the author, and by correcting the draft of this paper.

The non-occupational tolerance level for uranium (either U238 or U235) is 0.004 micro-curies. The occupational tolerance level is ten times this figure i.e. 0.04 micro-curies. Dale (S.R.H.P.), in report O-41/55, suggests that an operational hazard level of three times the occupational tolerance level is acceptable.

An additional factor quoted by S.W.P. (52/56/SWP) is that only 25% of fine particles of uranium inhaled are retained by the body. Summing these factors, it appears that approximately 0.5 micro-curies of uranium may be inhaled as an operational hazard.

The specific activity of natural uranium is 0.68 millicuries/kilogram. Approximately 50% of this activity arises from the U234 content. For the 93% enriched U235 supplied to A.W.R.E., the specific activity is almost exactly one hundred times that of natural uranium i.e. 68 millicuries/kilogram.

The factors determining the fall-out and air contamination from an incident such as is envisaged are:-

(1) The fraction of the R.A. material actually carried up in the cloud

It is apparently fairly well agreed (see SSWP/AWRE/TS.1230, 20/56/SWP and 52/56/SWP) that in the case of warheads such as Blue Danube and Red Beard, a similar incident will lead to a maximum of about 10% of the plutonium being finely divided and carried up in the cloud. S.W.P. feels that a linear scaling with increase of mass of R.A. material will certainly over-estimate the hazard arising. For the purpose of this paper, however, it is assumed 10% of the R.A. material in a warhead will be carried into the cloud as finely divided particles. This will certainly over-estimate the resultant hazard.

(2) The height to which the cloud rises

Figures at present available on cloud heights from H.E. explosions are as follows in Table I.

Table I. Cloud height related to weight of H.E.

Weight of H.E. (lbs.)	Height of cloud (ft.)
8$\frac{3}{8}$	109 82
1400	750 1150
5000	1610 2100

These values seem to follow the law that

$$h = 35W^{0.46}$$

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where h is the cloud height in feet, and M is the mass of H.E. in lbs.

It would, therefore, appear reasonable to assume that the detonation of various warheads will result in the cloud heights listed in Table II.

Table II. Cloud heights arising from detonation of a specific warhead

Warhead	[redacted]	Cloud Height (ft.)
Blue Danube	[redacted]	~1850
Red Beard	[redacted]	~520
Green Grass	[redacted]	~1000

The presence of an inversion layer may, of course, lead to lower cloud heights than those predicted above.

(3) The prevailing wind conditions

As will be shown later, increase of wind velocity will decrease the effective radius within which an ingestion hazard will arise. The fall-out will, of course, extend to a greater radius as the wind velocity increases.

(4) The particle size in the cloud

There is a great deal of uncertainty about the distribution of particle size that will arise from an incident of this nature. The size of the particles will determine their rate of deposition from the cloud, and hence the spread of contamination. It seems probable that particles varying in diameter from 1μ to 100μ will occur.

An approximate method of combining the variables governing the fall-out is given by S.W.P. in a note to D.D./A.W.R.E. (20/56/SWP). This method is quoted verbatim below.

"Siddons and Woodcock discuss the spread of fine dust produced by an explosion in terms of standard diffusion theory. In view, however, of the many uncertainties of atmospheric diffusion a more simplified treatment as follows would seem adequate. We consider the dust during the process of settling on the ground at some point, and suppose it is then distributed uniformly through a layer of vertical depth 'd'. If 'q' is the total activity deposited per unit area of the ground, then the activity per unit volume of the air during the settling process is (q/d). Let 'v' be the average settling velocity (including vertical diffusion); then the settling time of a layer of thickness 'd' is (d/v). Thus, if 'B' is the rate of breathing - volume of air inhaled per unit time - the amount 'I' of activity inhaled while the cloud is settling is

$$"I = Bq/v$$

"If 'h' is the height of the cloud, 'w' the wind speed, and 'x' the distance down-wind, the settling velocity also satisfies the equation

$$"v = wh/x$$

"and hence

$$"I = Bqx/wh$$

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"The ground contamination density 'q' will in general vary with position. However, the quantity we wish to determine is the ground contour within which the inhaled activity exceeds the specified hazard level. An upper limit of the area in this contour is obtained by assuming that all the activity is uniformly distributed within the contour. Also, we suppose that the contamination is predominantly deposited in a sector of a circle, of total angle θ radians, symmetric about the down-wind direction. The contaminated area to down-wind distance 'x' is thus θx^2, and, if this contains the total activity 'Q' released as fine dust, the average ground contamination density is

$$q = Q/\theta x^2$$

"Finally, therefore, the down-wind distance x within which exists an inhalation hazard I is given by

$$x = QB/wh\theta I"$$

Applying this theory to a few typical warheads, the results given in Table III are obtained.

Table III. Range at which an inhalation hazard exists for various warheads

The following constants are assumed:-

B = 20 litres/min.
W = 10 ft./sec.
θ = 0.1 radian ($\sim 6^\circ$, a fairly typical value for diffusion in a neutrally stable atmosphere).

I = 0.5 micro-curies.

Warhead	Blue Danube	Red Beard	Mixed Red Beard	Green Grass
Weight of U238 in warhead	[redacted]	[redacted]	[redacted]	[redacted]
Weight of U235 in warhead	[redacted]	[redacted]	[redacted]	[redacted]
Total curie content of warhead	[redacted]	[redacted]	[redacted]	[redacted]
No. of curies taken up in the cloud	[redacted]	[redacted]	[redacted]	[redacted]
Cloud height (feet)	1850	520	520	1000
Distance within which an inhalation hazard exists	Zero	Zero	3ft.	11ft.

From the above table it can be seen that an incident involving an H.E. explosion on a [redacted] will lead to an inhalation hazard only at small distances from the explosion, certainly only within the blast damage range.

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An additional hazard may arise from further disturbance of the dust after settling. It is felt that this hazard can be avoided by adequate control being established immediately after an incident has occurred.

The only experimental results to compare this with are those obtained by Holmes, S.H.P., in an as yet unpublished report. In this series of experiments carried out on the Buffalo minor trials, air samplers were sited at 15° intervals either side of the predicted ground wind. These samplers were approximately 100 yds. from the firing site. The results obtained are summarised in Table IV.

Table IV. Air contamination measurements on various Buffalo minor rounds

Weight of U238(Kgs.)	Weight of H.E. (lbs.)	Air contamination (x 8 hr. M.P.L)	Remarks
86.4	[redacted]	[redacted]	Dust blown from crater.
86.4	[redacted]	[redacted]	
57	[redacted]	[redacted]	

The above figures have been calculated using an 8 hr. maximum permissible level of 9×10^{-11} micro-curies/c.c. Thus if one assumes that at the worst, one gets 1/10 x M.P.L., the total amount inhaled in 8 hr. would only be 9×10^{-5} micro-curies. Even if the U238 were replaced with U235, no hazard would therefore exist.

The general conclusion to be drawn from these figures is that outside the region of major blast damage, no inhalation hazard will arise from an explosion involving a [redacted]

No experiments have yet been made on a system using U235, but no logical reason exists why the hazards should not be scaled directly in the ratio of the specific activities i.e. 100 to 1.

No consideration has been given in this report to the actual ground contamination resulting from an incident. This contamination does not constitute a direct hazard to humans, but may present a danger to grazing cattle. Again, however, rigorous Health Physics control of the area surrounding such an incident, followed by the removal of the surface layer of soil if necessary, make this hazard quite innocuous.

Summary

(1) For incidents involving an H.E. explosion on a [redacted] under no conditions will an inhalation hazard arise

(2) For incidents involving an H.E. explosion on a [redacted] there is just a possibility that the air contamination will exceed the 8 hour maximum permissible level. No hazard really exists, however, as the cloud will certainly deposit all the activity within a much shorter period than eight hours.

(3) No hazards will exist to humans due to the ground contamination from such an incident.

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(4) The hazards to grazing cattle from ground contamination can easily be removed by strict Health Physics control.

(5) It must be emphasised that any hazard that might arise would, of course, be of a long term nature.

[redacted]

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