2.3.3. SECTION III - BARRICADES: DESIGN CRITERIA

2.3.3.1. Functions of Barricades

1. General. The design criteria for a barricade depend on its location and the intended function.

2. Interception of High Velocity Projections

   a. An effective barricade intercepts high velocity projections from a PES which otherwise may cause practically instantaneous propagation of explosion to ammunition and explosives at an ES; the barricade therefore has sufficient resistance to high velocity projections to reduce their speed to a tolerable level. The geometry of the barricade in relation to the PES and the ES is such that it intercepts the projections through a sufficient, solid angle. When the barricade is subject to destruction by blast from the PES, it is designed to remain substantially intact for a sufficient time to achieve its purpose.

   b. An effective barricade reduces the number of high velocity projections which otherwise may endanger personnel and ES inside and outside the explosives area, but this is usually a secondary function.

3. Lobbed Ammunition and Fragments. An effective barricade also intercepts some lobbed items of ammunition and lobbed fragments but this is an incidental benefit. It is not usually practical to intercept items projected at a high elevation.

4. Modification of Blast and Flame

   a. A barricade at a PES may induce directional effects of the blast and flame or it may merely perturb them. This is a secondary function of a barricade, unless it is especially designed to achieve one or more of these purposes.

   b. A barricade between a PES and an ES may shield the ES from blast and flame. In order to have a marked shielding effect, the barricade is located close to the ES. The barricade may be part of the building-wall at the ES.

2.3.3.2. Geometry of Earth Barricades

1. General. Proper barricade geometry is necessary to reduce the risk that high velocity projections escape above or around the ends of the barricade and so produce an explosion in an adjacent site. Since such projections do not move along perfectly linear trajectories, reasonable margins in barricade height and length must be provided beyond the minimum dimensions which block lines of sight.

2. Height of Barricade

   a. Line AB

      (1) On level terrain point A is chosen as a reference on either of two stacks (see Figure 3-2). If the stacks have different heights, point A is on the lower stack. Point A is at the top of that face of the chosen stack which is remote from the other stack. If the stacks are covered by protective roofs, point A may be at the top of that face of the chosen stack which is nearer to the other stack (see Figure 3-2).

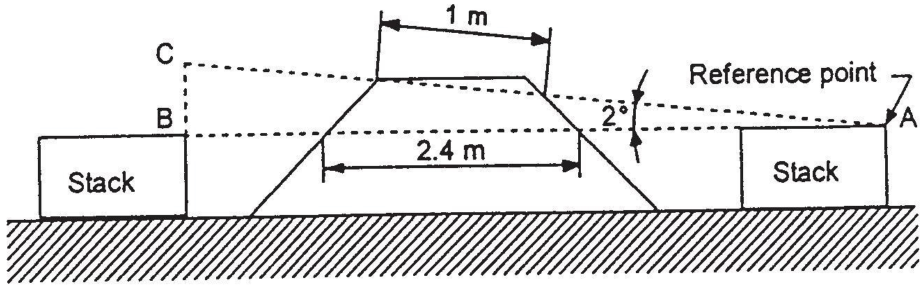

Figure 3-2: Determination of Barricade Height on Level Terrain

(2) On sloping terrain point A is on the stack whose top face is at the lower elevation (see Figure 3-3). Point A is at the top of that face of the chosen stack which is remote from the other stack.

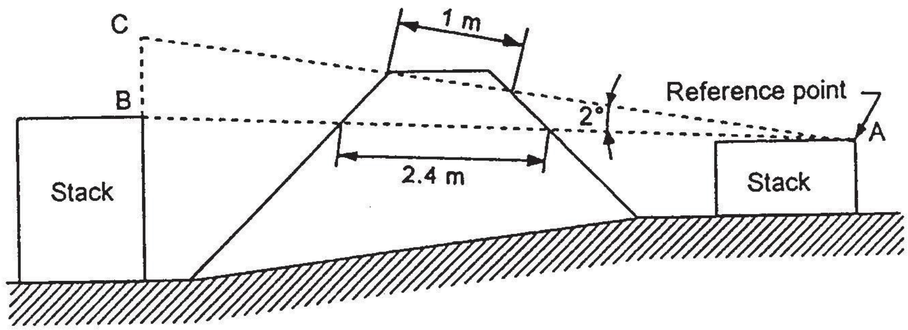

Figure 3-3: Determination of Barricade Height on Sloping Terrain

(3) If the stacks are covered by protective roofs, point A may be at the top of that face of the chosen stack which is nearer to the other stack. Point B is on the top face of the other stack (see Figure 3-3).

(4) Line AB must pass through at least 2.4 m of barricade material or undisturbed natural earth between the two stacks, whether or not they are contiguous.

b. Line AC (2 degree Rule)

(1) Point A is chosen in accordance with subparagraph 2.3.3.2 b) 1) above.

(2) On level or sloping terrain a second line (AC) is drawn at an angle of 2-degrees above line AB.

(3) On level terrain, when stacks are separated by less than 5 $Q^{1/3}$ whether or not they are contiguous, line AC must pass through at least 1.0 m of barricade material or undisturbed natural earth.

(4) On sloping terrain when the stacks are contiguous line AC must pass through at least 1.0 m barricade material or undisturbed natural earth.

(5) On sloping terrain when two stacks are not contiguous but the quantity distance between them is less than 5 $Q^{1/3}$, the 2-degree rule is not applicable.

c. Stacks separated by at least 5 $Q^{1/3}$

(1) When stacks, contiguous or not, are separated by the quantity distance 5 $Q^{1/3}$ or more, barricade requirements are assessed individually with respect to each stack.

3. Length of Barricade. The barricade length is determined by extending the barricade exclusive of the end slope to 1.0 m beyond lines between the extremes of the two stacks of ammunition under consideration. These lines must pass through at least 2.4 m of barricade material or undisturbed natural earth (see Figure 3-4).

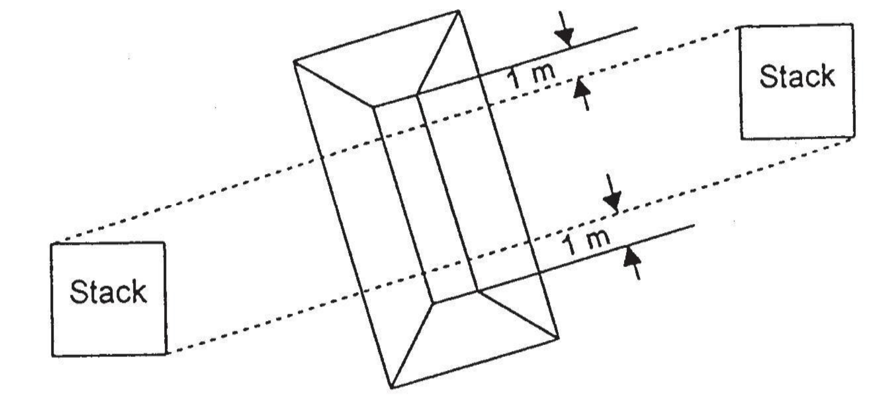

Figure 3-4: Determination of Barricade Length

4. Distance from Stack to Barricade

a. The distance from a stack to the foot of a barricade is a compromise. Each case is considered individually to achieve the optimum solution taking account of the following factors.

b. A barricade close to a stack results in smaller dimensions for the barricade to intercept high velocity projections through a given solid angle. However, on sloping terrain the minimum separation may not result in the smallest barricade.

c. A barricade further away from the stack results in easier access for maintenance and for vehicles, and the possibility to site the barricade outside the predicted crater, when the PES contains ammunition and explosives of HD 1.1. Avoidance of the crater is an advantage in some circumstances, see subparagraph 2.3.3.3.c). The barricade must be sited so that the crater does not undermine it more than one third of its thickness at ground level.

2.3.3.3. Material for Earth Barricades and for the Cover of Buildings

1. Earth for barricades and for cover of buildings should be made of material as prescribed below. When concrete or brick is used in conjunction with earth, either of these materials may be taken as equivalent to 4 times its thickness of earth with regard to the ability to stop fragments. The concrete or brick may be used to support the earth or it may

be those parts of the roof and walls of a building which intercept the high velocity projections.

2. There are two types of precaution which are necessary in the construction of earth barricades or the earth-cover for buildings used for storage of ammunition and explosives. One type relates to the potential hazards to other ammunition and to personnel in the event that the material is dispersed by an accidental explosion in the contained building. The other type relates to the precautions necessary to ensure structural integrity of the earth barricades or cover.

3. There is no need to consider the first type of precaution if it can be predicted that the material would not be dispersed by the postulated explosion. This will be the case if the barricade is sited beyond the crater radius. Scouring of the top surface by air blast can be neglected. The crater dimensions would be determined by the geometry of the stored explosives, their height above ground or depth of burial, and the nature of the ground. Unless the arrangement is particular asymmetrical, a good working estimate of the crater radius can be calculated from the formula:

$$\text{Crater radius (m)} = \tfrac{1}{2}\,(\text{NEQ (kg)})^{1/3}$$

This radius is measured from the centre of the explosives. In certain soil conditions (saturated soil or clay) the crater may be larger than calculated from the above formula (more complete information on cratering phenomenology is given in NATO document AC/258(ST)WP 211 PFP(CPG/TS-STSG)WP(99)2 Design Environment Criteria. In such conditions consideration should be given to increasing the Inter-Magazine Distances.

4. Where it is possible that the material would be dispersed by an explosion, precautions should be taken to reduce the hazard of large stones causing initiation by impact upon ammunition or explosives in adjacent storage sites. Where the storage site under consideration is near a densely occupied area, such as a group of explosives workshops, consideration should also be given to the hazard to personnel from flying stones etc. The selection of material and its use should be governed by the following prescriptions which represent a reasonable compromise between undue hazards and excessive costs of construction:

a. Do not deliberately use rubble from demolished buildings.

b. Ensure that stones larger than 0.3 m girth (about the size of a man's clenched fist) are removed during construction. Other deleterious matter should also be eliminated.

c. In climates where the ground becomes severely frozen, consideration should be given to the provision of an impermeable cover over the material or drainage to keep out excessive moisture.

5. The second type of precaution mentioned in subparagraph 2.3.3.3.2 above, relating to structural integrity, applies in all cases. For this purpose the material should be reasonably cohesive and free from excessive amounts of trash and deleterious organic matter. Compaction and surface preparation should be provided as necessary to maintain structural integrity and avoid erosion. Where it is impossible to use a cohesive material, for example at a site in a sandy desert, the earth-works should be finished with either a layer of cohesive soil or an artificial skin. On the other hand one should avoid solid, wet clay

during construction since this is too cohesive and would result in an excessive debris hazard.