U.S. Department
of Transportation
**Federal Aviation
Administration**

Subject: Calculation of Safety Clear Zones for Experimental Permits under 14 CFR § 437.53(a)

Date: February 28, 2011
Initiated by: AST-300

Guide No: 437.53-1
Change:

1. What is the purpose of this guide?

This guide provides one acceptable method for an experimental permit applicant or permittee to calculate the minimum dimension of a safety clear zone (SCZ) for hazardous pre-flight and post-flight launch operations, as required by 14 CFR § 437.53(a). The SCZ must be put into place and clear of the public before and during hazardous operations. In accordance with § 437.27, an applicant must demonstrate in its application how it will meet the requirement of § 437.53(a).

2. Who does this guide apply to?

This guide applies to operators of reusable suborbital rockets, using non-toxic, liquid propellants. A permittee must comply with § 437.53(a), which requires a permittee to establish a safety clear zone that will contain the adverse effects of each operation involving a hazard.

3. Definitions

Hazard division (HD) –A classification system for hazardous materials based upon their potential and mechanism for harm. See Reference [i] for more information.

Hazardous fragment – A debris fragment having a kinetic energy of impact at or above a threshold value corresponding to the impact energy capable of causing a serious injury or fatality. For purposes of this guide, a hazardous fragment is any fragment impact with a kinetic energy of 11 ft-lb or greater.

Hazardous fragment distance (HFD) – A distance measured from the point of explosion to the point at which the density of hazardous fragments generated by the explosion has decreased to where people in the open are not expected to be seriously injured. For purposes of this guide, the HFD is defined by an impact density of less than one hazardous fragment per 600 square feet.

K-factor – A scaling factor correlating the distance (D) and Net Explosive Weight (W) with a particular peak incident overpressure based on the Kingery-Bulmash relationship, as shown in Figure 1. See Reference [ii] for more information.

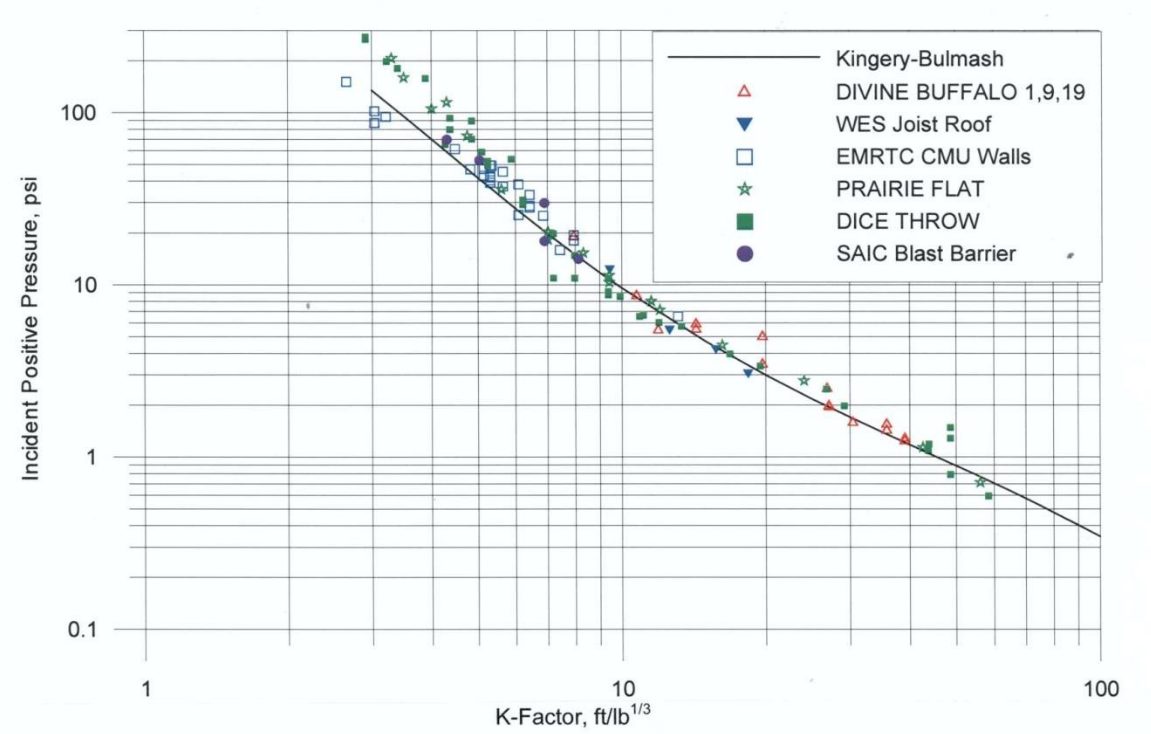

Figure 1: Kingery-Bulmash Relationship with Blast Test Data Points

Maximum credible event – A hypothesized worst-case accidental explosion, fire, or agent-release that is likely to occur from a given quantity and disposition of explosives, chemical agents, or reactive material.

Net Explosive Weight (W) – The total weight, expressed in pounds, of explosive material or explosive equivalency contained in an item. The explosive equivalent is the weight of a standard explosive, usually taken as trinitrotoluene (TNT), required to produce a selected shockwave parameter of equal magnitude at a specific location to that produced by a unit weight of the explosive in question.

Peak incident overpressure distance (D) – Distance measured from the point of explosion to the point at which the resulting overpressure has decreased to where people in the open are not expected to be seriously injured. For purposes of this guide, the threshold overpressure capable of causing serious injury is 1.0 psi.

Yield factor – The percentage of the total available explosive material used to compute the material's net explosive weight.

4. Safety Clear Zone Calculation

The regulations require an operator to create an SCZ that will contain the adverse effects of each pre-flight and post-flight launch operation involving a hazard. This guide provides an acceptable method to calculate an SCZ. The method assumes a maximum credible event, and provides the applicant with the most straightforward method of determining the SCZ's minimum dimension. In most cases, particularly those not involving the use of toxic materials, a maximum credible event consists of the explosion of all propellant on a vehicle and in any transfer containers. To create a safety clear zone based on a maximum credible event, a launch operator should employ the following steps:

a) Identify propellant type and quantity	A launch operator should determine the type and maximum weight of propellant planned to be present during pre-flight and post-flight operations. The total amount of propellant, not including inert pressurant, is at least the amount of propellant present in the vehicle tanks, including associated containers and

piping used to hold the liquid propellants for direct feeding into the engine.[1]

Example:

Assume Vehicle A contains the following combination of propellants at liftoff:
500 lb liquid oxygen (LOX)
500 lb RP-1

1,000 lb total propellant

b) Compute net explosive weight

A launch operator should compute the net explosive weight (*W*) of the propellants using a yield factor characteristic of the maximum credible event that may occur during pre-flight and post-flight operations.

Example:

Vehicle A uses RP-1 as a fuel, which is capable of causing an explosion when mixed with LOX. Table E-2 in Appendix E of 14 CFR part 420 suggests a yield factor no less than 20% for LOX/RP-1 for siting of launch vehicles. Therefore, a launch operator may apply the 20% value to Vehicle A.

$$W = 0.2 * 1000 = 200 \text{ lb}$$

c) Compute peak incident overpressure distance

A launch operator should compute an expected peak incident overpressure distance (*D*), as the distance measured from the point of explosion to the point at which the resulting overpressure has decreased to where people in the open are not expected to be seriously injured.

Example:

Vehicle A has propellants treated as a hazard division (HD) 1.1. By reading from the Kingery-Bulmash line in Figure 1, a peak incident overpressure of 1.0 psi corresponds to a K-factor of 45 ft/lb$^{1/3}$ *(17.85 m/kg*$^{1/3}$*). When subjected to a 1.0 psi overpressure, unstrengthened buildings can be expected to sustain damage that approximates less than 5% of their replacement cost, people in buildings are provided a high degree of protection from death or serious injury, and people in the open are not expected to be injured seriously by blast effects. The following equation is used to compute the peak incident pressure distance for Vehicle A.*

$$D = K \cdot W^{\frac{1}{3}}$$

$$D = 45 \cdot (200)^{\frac{1}{3}} = 263 \ ft$$

[1] If no positive means to prevent a credible accident from propellant mixing in feed lines or nearby supply or transfer tanks (e.g. mobile tanks used in propellant loading and unloading) exists, propellant in the feedlines and storage tanks should be included in the computation of the net explosive weight of propellants.

d) Compute hazardous fragment distance

A launch operator should compute the hazardous fragment distance (*HFD*) as the distance measured from the point of explosion to the point at which the density of hazardous fragments generated by the explosion has decreased to where people in the open are not expected to be seriously injured.

Example:

Use equation V3.E3.T2-1 of DoD 6055-09-M to compute the distance from the point of explosion to the point at which the density of hazardous fragments (those having an impact energy of 58 ft-lb (79 joules) or greater) has decreased to less than 1 hazardous fragment per 600 ft^2 *(55.7 m*^{2}*), based on the net explosive weight of the propellants in Vehicle A.*

If $W \geq 100$ *lb:*

$$HFD = -1133.9 + [389 \cdot \ln(W)]$$

$$HFD = -1133.9 + [389 \cdot \ln(200)] = 927\ \text{ft}$$

e) Determine minimum safety clear zone

A launch operator should set the minimum dimension of the safety clear zone to the **larger** of the hazardous fragment distance (*HFD*) or the explosive overpressure distance (*D*).

Example:

D = 263 ft, or HFD = 927 ft

Based on these results, the distance from a launch point to the edge of the safety clear zone should be no less than 927 ft for Vehicle A.

5. Summary

This guide represents one acceptable method used to determine a Safety Clear Zone. Other methods that offer an equivalent level of safety may be used. When combined with additional ground safety practices such as access control and sound mission procedures, this method may be used to build safety into hazardous pre-flight and post-flight operations.

6. Does this guide cancel any prior guide?

This guide is an original publication and does not cancel any previous documents

7. How can I get this and other FAA publications?

This guide and other FAA guidance regarding commercial space transportation can be viewed at http://www.faa.gov/about/office_org/headquarters_offices/ast/regulations/.

8. References

[i] "DOD Ammunition and Explosive Hazard Classification Procedures", TB 700-2 (http://www.ddesb.pentagon.mil/HazardClass/TB%20700_2%20%20A&E%20Hazard%20Classification.pdf) (January 1998).

[ii] Kingery, C. N. and Bulmash, G., "Airblast Parameters from TNT Spherical Air Burst and Hemispherical Surface Burst," ARBRL-TR-02555, Ballistic Research Laboratory, Aberdeen Proving Ground, MD, 1984.