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

Advisory Circular

Subject: De Minimis Far-Field Overpressure Blast Effects Analysis

Date: 09/10/2024
Initiated By: AST-1

AC No: 450.137-1

This Advisory Circular (AC) provides guidance on a simplified method for performing a Far-Field Blast Overpressure (FFBO) blast effects analysis as part of a flight safety analysis in accordance with Title 14 of the Code of Federal Regulations (14 CFR) 450.137. It is intended to assist prospective applicants in obtaining commercial space authorizations and operating in compliance with commercial space regulations for operations where FFBO hazards are de minimis (negligible). Specifically, this AC provides a method for applicants to screen the FFBO hazards associated with their flight and, where those hazards are negligible, to tailor their FFBO analysis in a manner that meets §§ 450.137(a)(1) and (b). In accordance with § 450.137(a), an applicant who elects to perform their FFBO analysis prior to the day of the operation does not need to analyze FFBO risk during the countdown as well.

The Federal Aviation Administration (FAA) considers this AC an accepted means of compliance for complying with the regulatory requirements of § 450.137(a)(1). This guidance is not legally binding in its own right and will not be relied upon by the FAA as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance is voluntary only and nonconformity will not affect rights and obligations under existing statutes and regulations.

If you have suggestions for improving this AC, you may use the Advisory Circular feedback form at the end of this AC.

DANIEL P MURRAY Digitally signed by DANIEL P MURRAY
Date: 2024.09.10 13:41:36 -04'00'

Daniel Murray,
Executive Director, Office of Operational Safety
Commercial Space Transportation

Table of Contents

Figures

Tables

1 PURPOSE.

1.1 This advisory circular (AC) provides guidance on a simplified method for performing a Far-Field Blast Overpressure (FFBO) effects analysis as part of a flight safety analysis in accordance with 14 CFR § 450.137. The FAA considers this AC an accepted means of compliance with the regulatory requirements of § 450.137.

1.2 In this context, “far-field” blast effect analysis refers to an assessment that accounts for peak incident overpressures below 1 pound per square inch (psi) or 6894 Pascal (Pa), which is the estimated threshold for which meteorological conditions can significantly influence the attenuation of explosive overpressures. Specifically, this AC addresses acceptable methods for assessing the potential for hazards to populations from broken window glass shards resulting from the airblast effects of large explosions that may be focused by certain conditions in the atmosphere through which the blast waves propagate. This phenomenon is sometimes referred to as distance focusing overpressure (DFO). Under certain conditions explained below, launch or reentry vehicles may be shown to present a de minimis or negligible risk from DFO, considering vehicle and mission profile characteristics.

1.3 Level of Imperatives.

This AC presents one, but not the only, acceptable means of compliance with the associated regulatory requirements. The FAA will consider other means of compliance that an applicant may elect to present. In addition, an operator may tailor the provisions of this AC to meet its unique needs, provided the changes are accepted as a means of compliance by the FAA. Throughout this document, the word “must” characterizes statements that directly follow from regulatory text and therefore reflect regulatory mandates. The word “should” describes a requirement if electing to use this means of compliance; variation from the provisions of this AC is possible but must satisfy the regulation to constitute an alternative means of compliance. The word “may” describes variations or alternatives allowed within the accepted means of compliance set forth in this AC.

2 APPLICABILITY.

2.1 The guidance in this AC is for launch and reentry vehicle applicants and operators required to comply with 14 CFR part 450, Launch and Reentry License Requirements. The guidance in this AC is for those seeking a launch or reentry vehicle operator license and a licensed operator seeking to renew or modify an existing vehicle operator license.

2.2 This AC provides a method for applicants to demonstrate that there are negligible risks from FFBO effects from the potential explosions caused by an intact vehicle (or stage) impact during a launch or reentry, and to accordingly tailor their FFBO analysis in a manner that meets §§ 450.137(a)(1) and (b). Explosions at altitude tend to have lesser ground amplification effects than surface explosions due to an intact impact. However, the burden of proof remains with the applicant to demonstrate to the FAA’s satisfaction that at-altitude explosions are negligible.

2.3 The material in this AC is advisory in nature and does not constitute a regulation. This guidance is not legally binding in its own right, and the FAA will not rely upon this guidance as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with this guidance document (as distinct from existing statutes and regulations) is voluntary only, and nonconformity will not affect rights and obligations under existing statutes and regulations.

2.4 The material in this AC does not change or create any additional regulatory requirements, nor does it authorize changes to, or deviations from, existing regulatory requirements.

3 APPLICABLE REGULATIONS AND RELATED DOCUMENTS.

3.1 Applicable United States Code (U.S.C.) Statute.

Title 51 U.S.C. Subtitle V, Chapter 509.

3.2 Related FAA Commercial Space Transportation Regulations.

The following 14 CFR regulations should be accounted for when showing compliance with 14 CFR 450.137. The full text of these regulations can be downloaded from the U.S. Government Printing Office e-CFR. A paper copy can be ordered from the Government Printing Office, Superintendent of Documents, Attn: New Orders, P.O. Box 371954, Pittsburgh, PA, 15250-7954.

- Section 413.15, *Review period.*
- Section 450.31(a)(6), *General requirements to obtain a vehicle operator license.*
- Section 450.101, *Public safety criteria.*
- Section 450.115*, Flight safety analysis methods.*
- Section 450.107*, Hazard control strategies.*
- Section 450.123, *Population exposure analysis.*
- Section 450.135, *Debris risk analysis.*
- Section 450.137*, Far-field overpressure blast effects analysis.*
- Section 450.145, *Highly reliable flight safety system.*
- Title 49, CFR, Subpart B, Chapter 1, Subchapter C, Part 173.

3.3 Related Industry Documents.

1. Allahdadi, Firooz A., Isabelle Rongier, Tommaso Sgobba, and Paul D. Wilde, *Safety Design for Space Operations*, Sponsored by The International Association for the Advancement of Space Safety (IAASS), Elsevier, Watham, MA, dated 2013.
2. American National Standard ANSI S2.20-1983, *Estimating Airblast Characteristics for Single Point Explosions in Air, with a Guide to Evaluation of Atmospheric Propagation and Effects*, Standards Secretariat, Acoustical Society of America, New York, NY, 1983.
3. Blackwood, James M., Troy Skinner, Erin H. Richardson, and Michal E. Bangham, *An Empirical Non-TNT Approach to Launch Vehicle Explosion Modeling*, American Institute of Aeronautics and Astronautics, dated January 5, 2015.
4. Devoid, W. and C. Wass, *Final PIRAT Yield Model for Impacting Solid Propellant*, Revision 2, Report No. CSR3-00300-R2, A-P-T Research, Inc. Cocoa Beach, FL, dated September 16, 2011.
5. Elwell, R.B., Irwin, O.R., Vail, R.W., Jr. Project Sophy, *Solid Propellant Hazards*, Aerojet-General Corporation, dated September 30, 1966.

Note: The industry and government documents referenced in this chapter refer to the current revisions or regulatory authorities' accepted revisions.

3.4 Related U.S. Government Documents.

1. Department of Defense *DOD Defense Explosives Safety Regulation (DESR)*, DoD 6055.09, Edition 1, Change 1, Department of Defense Explosives Safety Board (DDESB), dated February 23, 2024.
2. Min, I. A., and R. Walterscheid. "*Overpressure calculation for BLASTC,*" memorandum, dated 2001.
3. Needham, Charles E., and Joseph E. Crepeau. "*The DNA Nuclear Blast Standard (1KT)*" DNA 5648T, Defense Nuclear Agency, Alexandria, VA, dated 1981.
4. Swisdak, Michael M., "*Simplified Kingery Airblast Calculations,*" Minutes of the 26th DoD Explosives Safety Seminar, Naval Surface Warfare Center. August 1994.

3.5 Related FAA Advisory Circulars.

FAA Advisory Circulars (are available through the FAA website, http://www.faa.gov). Some of these are not yet published.

- AC 450.115-1A, *High Fidelity Flight Safety Analysis,* dated June 24, 2021.
- AC 450.123-1, *Population Exposure Analysis,* dated October 12, 2022.

4 DEFINITION OF TERMS.

For this AC, the definitions from § 401.7 and the following apply.

4.1 Caustic

A sonic velocity profile with a sonic velocity decreasing initially at altitudes above ground before increasing at greater altitudes. This results in an increased intensity of the blast wave as sensed at the ground level, potentially posing greater blast risks in some distant locations than other sonic velocity profiles. As the altitude increases, the slope of the sonic velocity profile may change multiple times.

4.2 Far-Field overpressure (Distant focusing overpressure)

Air shock overpressure amplified by atmospheric conditions in the far-field. This typically applies to overpressures of less than 1 psi or 6894 Pascal (Pa).

4.3 Far-field

Distances from an explosion with overpressures of typically less than 1 psi or 6894 Pascal (Pa).

4.4 Impulse

Area under the curve of an airblast wave pressure time history in the positive phase.

4.5 Maximum range

Here this refers to the maximum range of the FFBO hazard and is defined as the distance between the maximum credible explosive yield event location, for each phase of flight, and the point where the peak incident overpressure would not exceed 200 Pa under focusing conditions with a focus factor equal to 2.0.

4.6 Overpressure

Peak value of an airblast wave pressure time history above ambient pressure.

4.7 Project PYRO

A large-scale liquid propellant test program conducted in the 1960’s, which provided a basis for much of the liquid propellant blast yield models historically used in flight safety analysis for intact impacts following its completion.

4.8 Yield

Trinitrotoluene (TNT) equivalent blast potential, based on either peak overpressure or impulse.

5 ACRONYMS.

AC – Advisory Circular

AST – FAA Office of Commercial Space Transportation

A50 – Aerozine 50

ANSI – American National Standards Institute

AST – FAA Office of Commercial Space Transportation

CAS – Cylindrical Annulus Sector

CFR – Code of Federal Regulations

DDESB – Department of Defense Explosive Safety Board

DESR – Defense Explosives Safety Regulation

DFO – Distance Focusing Overpressure

FAA – Federal Aviation Administration

FFBO – Far-Field Blast Overpressure

FSA – Flight Safety Analysis

FSS – Flight Safety System

HD – Hazard Division

IAASS – International Association for the Advancement of Space Safety

IRFNA – Inhibited Red Fuming Nitric Acid

LH2 – Liquid Hydrogen

LOX – Liquid Oxygen

MMH – Monomethyl Hydrazine

PERMS – Propellant Impact Response to Mechanical Stimulus

PIRAT – Propellant Impact Response Assessment Team

PYRO – Greek word for fire

RP-1 – Rocket Propellant-1

TNT – Trinitrotoluene

UDMH – Unsymmetrical Dimethyl Hydrazine

U.S. – United States

U.S.C. – United States Code

6 BACKGROUND.

6.1 Part of the safety analysis is concerned with risks to populations from broken window glass shards resulting from the airblast effects of large explosions that may be focused by certain conditions in the atmosphere through which the resulting blast waves propagate. Section 5.2 of the International Association for the Advancement of Space Safety (IAASS) publication, *Safety Design for Space Operations*[1] provides supplemental information relevant to FFBO analyses.

[1] Allahdadi, Firooz A., Isabelle Rongier, Tommaso Sgobba, and Paul D. Wilde, *Safety Design for Space Operations*, Sponsored by The International Association for the Advancement of Space Safety (IAASS), Elsevier, Watham, MA, dated 2013

7 ACCEPTABLE METHODOLOGY.

7.1 Topics Covered by this AC.

This AC provides a method for applicants to demonstrate that there are negligible risks from FFBO blast effects from the potential explosions caused by impact during a launch or reentry, and to accordingly tailor their FFBO analysis in a manner that meets §§ 450.137(a)(1) and (b). If the maximum credible yield input (developed in accordance with paragraph 7.5 of this AC) to the deterministic no damage yield analysis (shown in Figure 5 of this AC) indicates that no public population centers are vulnerable to window breakage, then the hazards from FFBO are negligible. The method described here is referred to as a screening method because it is appropriate to demonstrate when a FFBO risk analysis method is unnecessary. The FAA finds that use of the screening method outlined in this AC to demonstrate that there are negligible risks from FFBO blast effects, and to accordingly tailor a FFBO to meet §§ 450.137(a)(1) and (b), provides a level of fidelity sufficient to satisfy § 450.115(b). As such, an applicant utilizing the means of compliance outlined in this AC need not submit further evidence of compliance with § 450.115 for the FFBO methodology used to meet § 450.137.

7.2 Explosive Capability of the Vehicle.

7.2.1 In accordance with § 450.137(b)(1), an analysis must account for the explosive capability of the vehicle and hazardous debris at impact and at altitude. The preamble to the final rule made it clear that § 450.115 applies to all flight safety analysis (FSA) methodologies, including FFBO analyses. In accordance with § 450.115(a) an operator's flight safety analysis must account for all reasonably foreseeable events and failures of safety-critical systems during nominal and non-nominal launch or reentry. Thus, for each phase of flight within the scope of the FSA, the screening analysis should compute a maximum credible yield that accounts for any foreseeable scenario during flight that would be expected to generate an explosion, including ground impacts and on-trajectory explosions involving liquid or solid propellants.[2] In addition to foreseeable ground impact scenarios involving the vehicle and vehicle stages, the maximum credible yield should account for a potential explosion following a collision with the launch tower (if any) or any other structures. The yield from an intact impact is generally larger than the explosive yield from a breaking up in the air.

The analysis of the explosive capability of the vehicle should also account for:

- The vehicle mass, geometry, propulsion, and performance characteristics.
- The energetic material types onboard the vehicle whether solid, liquid, or gas.
- The effects of the impact velocity and impact surface hardness on the explosive response of the impacting energetic materials.

[2] Failure modes that result in an uncontrolled disposal are a potential exception.

- The potential for an intact impact given the time delay, including uncertainties, between the violation of a flight abort rule and the time when the flight safety system (FSS) is expected to activate; and
- The potential for the FSS to fail, unless the FSS meets the requirements of a highly reliable FSS in § 450.145.

7.2.2 The impact velocity should assume no drag account for aerodynamic drag or use conservate estimates of drag forces prior to impact.

7.3 **Liquid Propellant Yield**.

7.3.1 A screening analysis should use the Project PYRO results shown in Fig. 1 to compute an upper-bound yield factor as a function of impact velocity for three common combinations of oxidizer and fuel:

1. Cryogenic liquid oxygen and liquid hydrogen (LOX/LH2).
2. Cryogenic liquid oxygen and Rocket Propellant–1 (LOX/RP-1).
3. Hypergolic propellants, consisting of a liquid oxidizer such as nitrogen tetroxide (N2O4) or inhibited red fuming nitric acid (IRFNA) combined with a liquid fuel such as monomethyl hydrazine (MMH), unsymmetrical dimethyl hydrazine (UDMH) or Aerozine-50 (A50).

7.3.2 The yield factor is defined as the ratio of the equivalent weight of TNT to the weight of the propellant involved in the explosion, based on the air shock overpressure generated in surface level (hemispherical) explosions. The yield factors are expressed as functions of the impact velocity magnitude, i.e., the speed at which the propellant tanks impact the surface causing breakup. The terms ‘impact velocity’ and ‘impact speed’ are used interchangeably in this context.

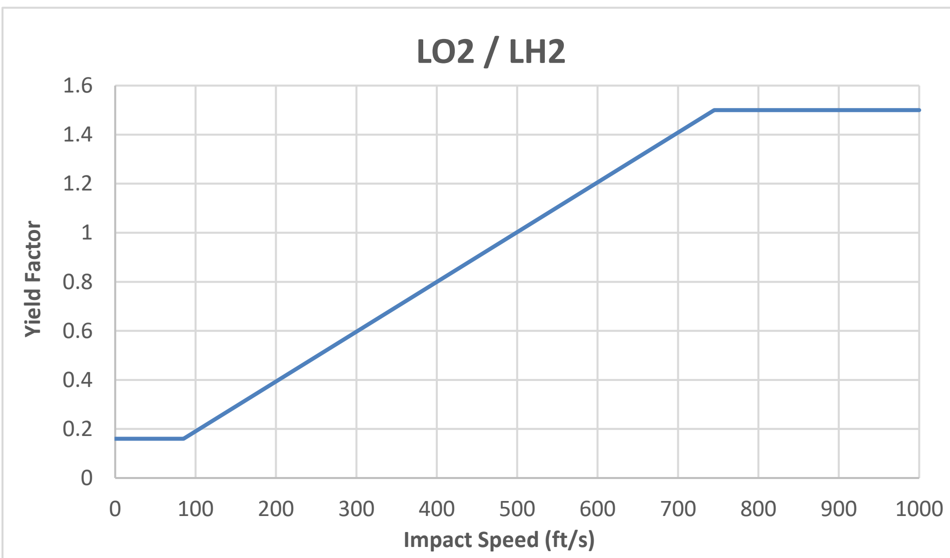

Figure 1 – Yield Curve for Impacts of Liquid Oxygen and Liquid Hydrogen Propellant

7.3.3 Data from actual launch vehicle impacts show that for public safety purposes, impacts on soft surfaces, including sand, soft soil, and water, may be treated as hard surface impacts. Consequently, no distinction between the two types of surfaces is required. Thus, Table 1 of this AC shows the data points that should be used to construct piecewise linear functions for the yield factor from any impact of these three liquid propellants.

Table 1 – Liquid Propellant Yield Model Tabular Values

LOX/LH2		LOX/RP1		Hypergols	
Impact Speed fps	Yield Factor lb. TNT/lb.	Impact Speed fps	Yield Factor lb. TNT/lb.	Impact Speed fps	Yield Factor lb. TNT/lb.
0	0.16	0	0	0	0.020
85	0.16	170	0.215	100	0.085
745	1.50	800	0.215	200	0.135
800	1.50			300	0.180
				400	0.220
				500	0.245
				600	0.260
				700	0.275
				800	0.280

7.3.4 Although some liquid monopropellants are used in rocket propulsion, liquid propellants for which yield factor models have been developed for use in FFBO risk analysis are most commonly bipropellants. These consist of separate fuel and oxidizer components that are combined in liquid propellant engines to propel the vehicle. For other propellant types, the explosive yield factor curve should be based on the best available explosive yield data for the corresponding type or class of solid or liquid propellant based on empirical data or computational modeling. The TNT equivalence for explosive events addressed in defense explosives safety regulation (DESR) 6055.9[3] are considered valid by the FAA; applicants should consult with the FAA to determine when these scenarios are deemed applicable by the FAA.

7.4 Solid Propellant Yield

7.4.1 Solid propellants relevant for flight safety analysis are typically represented in one of two categories: Hazard Division (HD) 1.1 detonable propellants, or HD 1.3 deflagration propellants[4]. For other types of solid propellant, a conservative option is to apply the HD 1.1 model. The yield factors for solid propellant should account for the size and shape of the propellant, type of impact surface, total impact speed, and orientation at impact if applicable.

7.4.2 For HD 1.1 impacts, yield factor F_{TNT} values for various surface types should be based on Figure 2 of this AC. This plot indicates that the factor will either be 0 or 1.25 depending on the impact velocity. These curves make no distinction of whether the propellant is in a contained motor, its impact orientation, or uncontained hazardous debris created at vehicle breakup.

[3] Department of Defense *DOD Defense Explosives Safety Regulation (DESR)*, DoD 6055.09, Edition 1, Change 1, Department of Defense Explosives Safety Board (DDESB), dated February 23, 2024.
[4] Title 49, Code of Federal Regulations, Subpart B, Chapter 1, Subchapter C, Part 173.

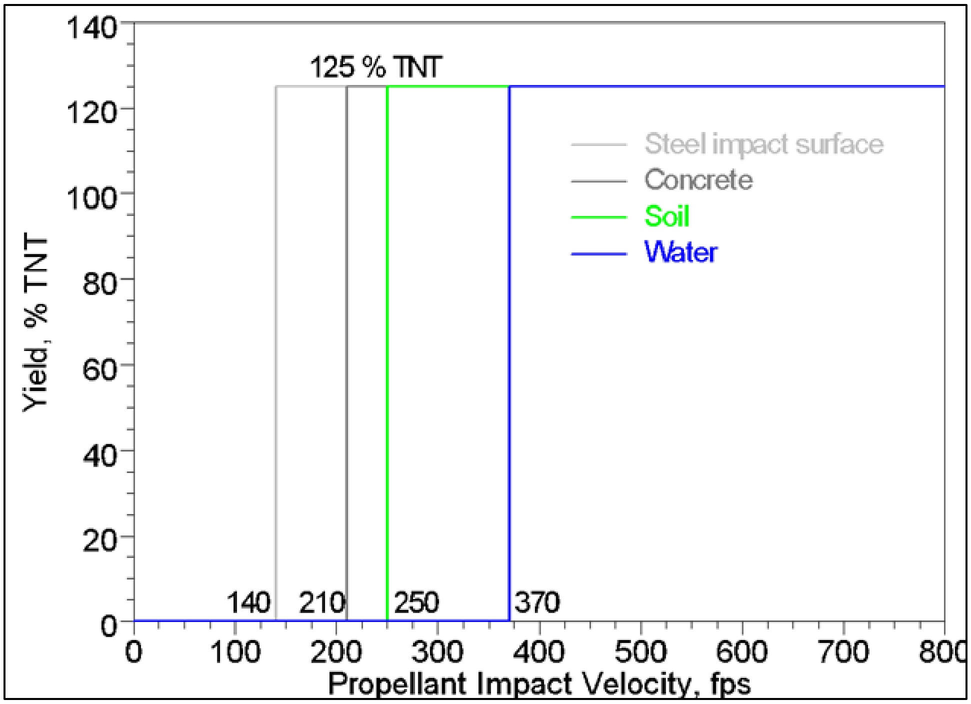

Figure 2 – Hazard Division 1.1 Propellant Yield Model

7.4.3 For HD 1.3 propellant impacts[5], the screening analysis should assume that all solid rocket motors remain intact and impact in a side-on orientation. Yield factors for intact motor segments that impact on sand in a side-on orientation may be obtained from the curves in Figure 3 of this AC, where the segment sizes are measured by the lateral diameter of the motors. If the yield factor associated with the desired motors is not those presented in the figure or are not available, then the curves in Figure 3 of this AC should still be used. For other motor diameters between 41" and 146," linearly interpolate between the nearest bounding curves. For diameters outside the range, use the closest bounding curve and do not extrapolate.

[5] Title 49, Code of Federal Regulations, Subpart B, Chapter 1, Subchapter C, Part 173.

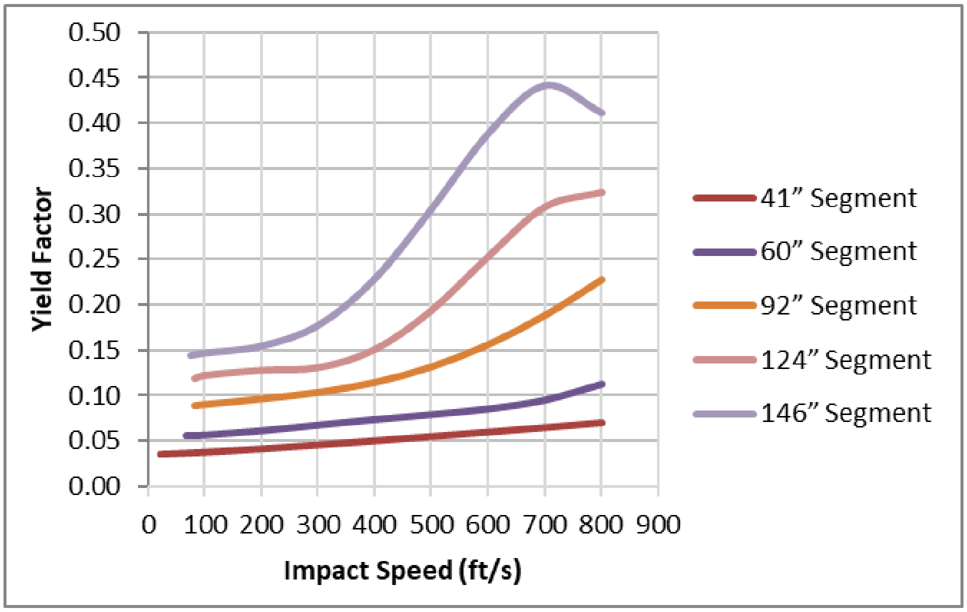

Figure 3 – Yield Curves for HD 1.3 Propellant

The following equation should be used to compute the yield factors as a function of impact speeds for a variety of motor sizes that use HD 1.3 propellants.

$$TNT\ Yield\ Factor = aS^4 + bS^3 + cS^2 + dS + e$$

where

S	=	Impact speed (feet per second)
a-e	=	Equation coefficients (pounds TNT per pound propellant)

7.4.4 Tables 3, 4, and 5 in appendix A of this AC list the coefficients that should be used with this equation to compute the yield factor for side-on motor impacts on sand.

7.4.5 For surface types other than sand or soft soil impact, adjust the impact speed by:

$$v = \frac{v_{impact}}{F_{surface}}$$

where is $F_{surface}$ 0.55 for steel, 0.78 for concrete, 1.00 for sand, and 1.61 for water.

7.5 **Sympathetic Yields**.

7.5.1 The maximum credible yield should account for the potential for sympathetic yields when multiple motors and/or engines can impact near one another during the same event. If the motors or engines have different propellant compositions, then the yields should be computed separately, and not combined to estimate the maximum credible yield. If a vehicle that uses multiple motors or engines with the same propellant composition is expected to impact intact, then the propellant involved in the explosion should account for the total of all the propellants on the vehicle unless the applicant can demonstrate that a vehicle impact would result in explosions that are sufficiently separated by time or distance to be treated as separate explosions for the purpose of an FFBO analysis. For example, explosions that are coincident in terms of location, but are separated by at least 0.3 seconds may be treated as separate explosions. If insufficient information exists for such an evaluation, then the screening analysis should combine the propellant weights and use this as a single yield.

7.5.2 In accordance with § 450.137(c)(2), an application must include, at a minimum, a description of the methods used to compute the foreseeable explosive yield probability pairs, and the complete set of yield-probability pairs, used as input to the far-field overpressure analysis. A deterministic screening method should assume a probability of one for the maximum credible yield.

7.6 **Exposed Windows and Populations Susceptibility to Injury.**

7.6.1 In accordance with § 450.137(b)(3), an analysis must account for the characteristics of exposed windows and the population's susceptibility to injury. Thus, a critical input to any valid screening method is a description of the population centers and potentially inhabited structures that could be subject to an FFBO hazard.

7.6.2 In general, an FFBO analysis should use population data that complies with the requirements of § 450.123. AC 450.123-1 provides guidance on population analyses that could be used to establish the population input data for FFBO screening analysis.

7.6.3 In accordance with § 450.123(a), an FSA must account for the distribution of people for the entire region where there is a significant probability of impact of hazardous debris. The extent of the region should consider all types of hazardous debris (as defined in § 401.7), which accounts for hazards from explosive and toxic substances, as well as potential for consequences due to either planned operations (e.g., jettisons) or reasonably foreseeable failures.

7.6.4 To identify the extent of the region that includes population centers and potentially inhabited structures that could be susceptible to an FFBO hazard, the applicant should compute the distance between the maximum credible explosive yield event location for each phase of flight and the point where the peak incident overpressure would not exceed 200 Pa under focusing conditions with a focus factor equal to 2.0, referred to here as the maximum range of the FFBO hazard. Figure 4 of this AC (replicated from Figure 5.2.5 of the IAASS publication) shows that the 69 Pa (0.01 psi) peak incident overpressure threshold corresponds to a negligible probability of breakage for typical populations surrounding the two major launch sites in the U.S. In addition, ANSI Standard S2.20-1983[6] reported this threshold peak incident overpressure corresponds "in practice to the threshold level at which claims for window damage begin" based on recordings from nuclear tests.

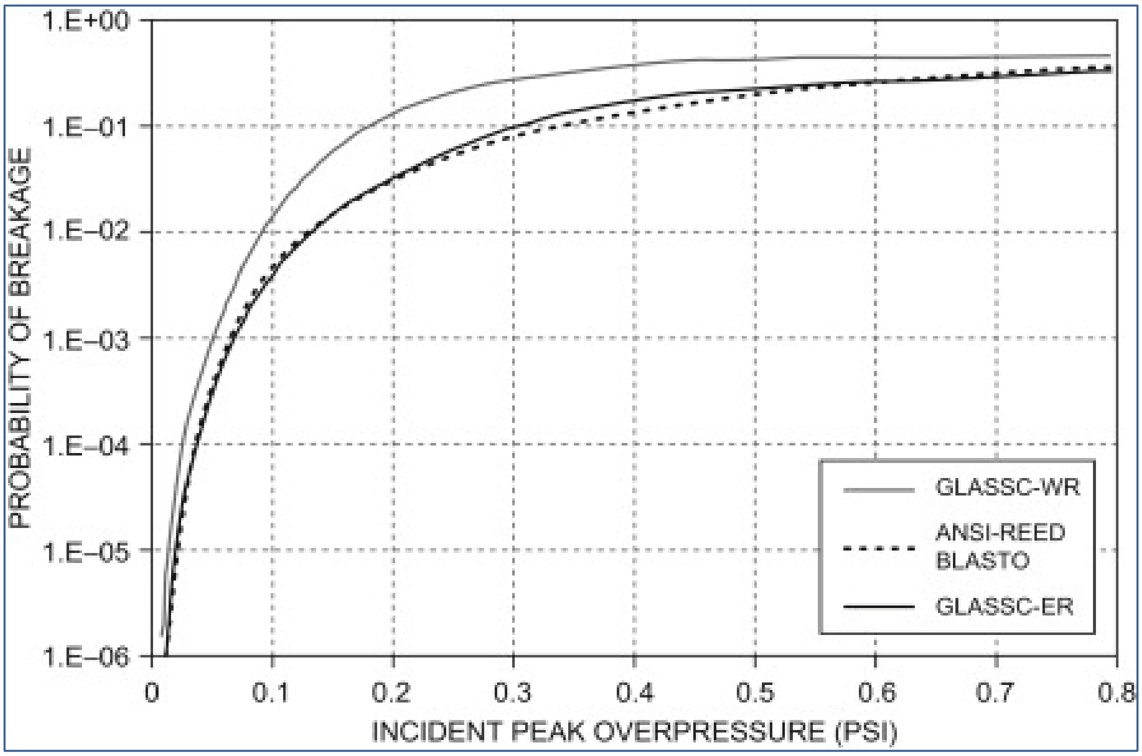

Figure 4 – Probability of breakage for average windowpanes near Vandenberg, CA and Cape Canaveral, FL[7]

[6] American National Standard ANSI S2.20-1983, *Estimating Airblast Characteristics for Single Point Explosions in Air, with a Guide to Evaluation of Atmospheric Propagation and Effects*, Standards Secretariat, Acoustical Society of America, New York, NY, 1983.

[7] Figure 5.2.5 of Allahdadi, Firooz A., Isabelle Rongier, Tommaso Sgobba, and Paul D. Wilde, *Safety Design for Space Operations*, Sponsored by The International Association for the Advancement of Space Safety (IAASS), Elsevier, Watham, MA, dated 2023.

7.6.5 A screening analysis should use the following equation (which is equation 14 in the IAASS publication) to compute the distance from between the maximum credible explosive yield event location for each phase of flight and the point where the peak incident overpressure would not exceed 69 Pa under focusing conditions with a focus factor equal to 2.0.

$$\Delta P = \left(F_{foc}\right)1.864(10^5)(F_{HOB}W)^{0.4}R^{-1.2}$$

ΔP = Incident peak blast overpressure in Pascals (Pa)

F_{foc} = Focus factor

R = Nearest distance from explosion to population center in meters

W = Net explosive yield (charge weight) in kg TNT

F_{HOB} = Height of Burst factor, which is 2 for a ground explosion

7.6.6 A screening analysis should use a Height of Burst factor of 2, which conservatively represents a perfect reflection from a hard surface.

7.6.7 For each phase of flight where an explosion is foreseeable, the screening method should identify the population centers within the maximum range of the FFBO hazard of the maximum credible explosive event. In addition, for any single potentially inhabited structure within the distance defined by the “no-damage yield” for a single residence based on Figure 5 of this AC (replicated from Figure 5.2.3 of the IAASS publication), the screening method should identify the number, size, and type of windows that face within 90 degrees of the azimuth from the maximum credible explosive yield location to the single structure location. The screening analysis should identify windows of different types and differentiate between annealed, tempered, dual paned and film covered. Window size categories should be based on typical windows found in the local populated areas and differentiate between pane areas that differ by a factor of two at the most.

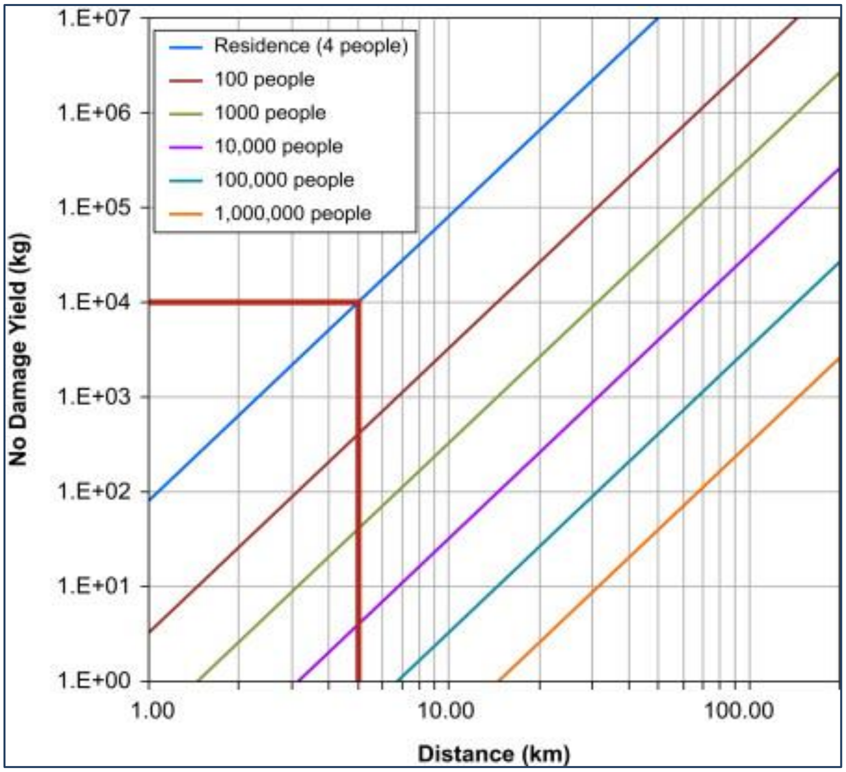

Figure 5 – No-damage limits for surface explosions (ANSI standard Figure 26)[8]

[8] Figure 5.2.3 of Allahdadi, Firooz A., Isabelle Rongier, Tommaso Sgobba, and Paul D. Wilde, Safety Design for Space Operations, Sponsored by The International Association for the Advancement of Space Safety (IAASS), Elsevier, Watham, MA, dated 2023.

7.6.8 If the total area of annealed glass panes that face the maximum credible explosive yield location for a given phase of flight ***exceeds 40 square feet*** (which is typical for a residence), then the screening method described in this AC ***cannot*** be used to satisfy the requirements of § 450.137 for that phase of flight.

7.6.9 Populations located in vehicles that meet U.S. standards need not be accounted for in an FFBO screening analysis (because the glass used in U.S. vehicles are not a credible source of FFBO hazards). The FFBO can also ignore any population centers that would be subject to a peak incident overpressure above 1.0 psi or 6894 Pascal (Pa), given the maximum credible explosive event because § 450.137(b)(3) requires the FFBO analysis to account for the potential for broken windows due to peak incident overpressures below 1.0 psi only. However, any population center exposed to a peak incident overpressure above 1.0 psi given the maximum credible explosive event, including people in vehicles that meet U.S. standards, would generally need to be accounted for in the debris risk analysis in accordance with § 450.135.

7.7 Deterministic Screening Method.

7.7.1 If the maximum credible yield input (developed in accordance with paragraph 7.5 of this AC) to the deterministic no-damage yield analysis (shown in Figure 5 of this AC) indicates that no public population centers are vulnerable to window breakage, then the hazards from FFBO are negligible, and the FFBO analysis complies with §§ 450.137(a)(1) and (b) based on this deterministic screening method.

7.7.2 A simple example of the deterministic screening method results is summarized in Table 2 of this AC. In this case, the maximum credible yield was determined to be 1,000 Kg TNT equivalent at the launch point. The closest population centers are

1. A single residence 3 km away from the launch point,
2. A village of 100 people 8 km away from the launch point,
3. A small town of 10,000 people 40 km away from the launch point, and
4. A city of 1,000,000 people 150 km away.

7.7.3 This is an example where the deterministic method demonstrates negligible FFBO risks because the actual distance from the closest edge of each population center to the location of the maximum credible yield event exceeds the distance corresponding to the "no damage yield" given by Figure 5 of this AC as shown in the Table 2.

Table 2 – Sample Description of Results from the Deterministic Screening Method

Population Center Name	Number of People	Distance from population center to explosion (km)	No Damage Distance (km)
Closest Residence	<=4	3	2.2
Village	100	8	7
Small Town	10,000	40	30
City	1,000,000	150	130

8 SATISFYING APPLICATION REQUIREMENTS

A far-field overpressure risk analysis submitted for compliance with the safety criteria in § 450.101 must be sufficiently documented by an operator in their application for a launch or reentry license to show that related regulatory requirements have been met. This analysis should include a description of the far-field overpressure analysis, including all assumptions and justifications for the assumptions, analysis methods, input data, and results. The following sections describe the minimum details that the application should provide and sample calculations for a simplified screening analysis.

8.1 Terrain and Population Data.

8.1.1 In accordance with § 450.137(c)(1), a far-field overpressure risk analysis submitted for compliance with the safety criteria in § 450.101 must include a description of the relevant characteristics of the general region surrounding the explosion used as input to the far-field overpressure analysis, including a description of population centers, terrain, building types, and window characteristics. To fulfill this application requirement using the screening methods identified in the AC, an applicant should provide the following.

1. A list that includes the location (latitude and longitude) and population of each population center that contains at least one potentially inhabited structure within the maximum range of the FFBO hazard for each phase of flight. The population of any population center that consists of a single residential structure should be listed as less than or equal to four in the absence of more accurate information.
2. A list of the number, size, and type of windows that face within 90 degrees of the azimuth from the maximum credible explosive yield location to the single structure location for each potentially inhabited structure within the distance defined by the "no-damage yield" for a single residence and the maximum credible explosive yield based on Figure 5 of this AC (replicated from Figure 5.2.3 of the IAASS publication). The description of window types should differentiate between annealed, tempered, dual paned and film covered. Window size categories should be based on typical windows found in the local populated areas and differentiate between pane areas that differ by a factor of two at the most.
3. A table, such as shown in Table 2 of this AC, that identifies the closest population centers to each maximum credible explosion location that have populations of at least 100, 1,000, 10,000, 100,000, and 1,000,000 people, as well as the closest single potentially inhabited structure.
4. A general description of the building types located in each of the population centers listed in the table provided to identify the closest population (in response to #3 of this list). The general description should identify, at a minimum, the following structure types located within each population center: mobile homes and trailers, single family residences, multi-family residences with no more than three-stories, residential structures with more than three-stories, commercial buildings of all kinds with no more than three-stories (including retail, offices, restaurants, gas stations, strip malls) and commercial and industrial buildings of all kinds with more than three -stories (including large retail, offices, warehouses, manufacturing, and malls).

5. A general description of the terrain within the maximum range of the FFBO hazard for each phase of flight. The general description should identify, at a minimum, the following terrain types: flat with land and/or water boundaries, and hilly with maximum elevation change.

8.1.2 In accordance with § 450.137(c), a far-field overpressure risk analysis must include description of the far-field overpressure analysis, including all assumptions and justifications for the assumptions, analysis methods, and input data. To fulfill this application requirement using the screening methods identified in the AC, an applicant should provide the following.

1. A description of the source of the data provided above, such as census data, physical surveys, and satellite imagery.
2. A description of the dates for the source data, and any methods used to update the data to account for changes that could occur prior to the date of the operation.

8.2 **Explosive Yield-Probability Pairs.**

8.2.1 In accordance with § 450.137(c)(2), a far-field overpressure risk analysis must include a description of the methods used to compute the foreseeable blast yields probability pairs, and the complete set of yield-probability pairs, which are used as input to the far-field overpressure risk computations. Thus, an FFBO should include a description of how the explosive yield was computed for all phases of flight where an FFBO hazard was analyzed.

8.3 **Overpressure Computations.**

8.3.1 In accordance with § 450.137(c)(3), a far-field overpressure risk analysis must include a description of the methods used to compute peak incident overpressures as a function of distance from the explosion and prevailing meteorological conditions, including sample calculations for a representative set of the foreseeable meteorological conditions, yields, and population center distances from the explosion.

8.3.2 For a screening analysis performed in accordance with this AC, an FFBO analysis should:

1. Identify the equation used to peak incident overpressures as a function of distance (i.e., equation).
2. A list of the input and output values for the equation used to compute the peak incident overpressure for each of the closest population centers that have populations of at least 100, 1,000, 10,000, 100,000, and 1,000,000 people, as well as the closest single potentially inhabited structure.
3. List the maximum range of the FFBO hazard analysis for each phase of flight.
4. Note that the prevailing meteorological conditions were conservatively assumed to produce caustic focusing on every population center within the maximum range of the FFBO hazard for each phase of flight.

8.4 Window Breakage.

In accordance with § 450.137(c)(4), a far-field overpressure risk analysis must include a description of the methods used to compute the probability of window breakage. For a screening analysis performed in accordance with this AC, an FFBO analysis should state that the probability of breakage was based on the glass damage model described in ANSI Standard S2.20-1983.

8.5 Probability of Casualty Computations.

In accordance with § 450.137(c)(5), a far-field overpressure risk analysis must include a description of the methods used to compute the probability of casualty for a representative individual, including tabular data and graphs for the probability of casualty, as a function of location relative to the window and the peak incident overpressure for a representative range of window types, building types, and yields accounted for. For a screening analysis performed in accordance with this AC, an FFBO analysis should state that the method assumes that no casualties can occur from the maximum credible yield for each phase of flight because every population center within the maximum range of the FFBO hazard is located beyond "no-damage yield" range based on Figure 5 of this AC (replicated from Figure 5.2.3 of the IAASS publication).[9]

[9] Allahdadi, Firooz A., Isabelle Rongier, Tommaso Sgobba, and Paul D. Wilde, *Safety Design for Space Operations*, Sponsored by The International Association for the Advancement of Space Safety, Elsevier, Watham, MA, dated 2013.

8.6 Probability of Casualty Threshold Locations.

In accordance with § 450.137(c)(6), a far-field overpressure risk analysis must include tabular data and graphs showing the location of any individual member of the public that could be exposed to a probability of casualty of 1×10^{-5} or greater for neighboring operations personnel, and 1×10^{-6} or greater for other members of the public, given foreseeable meteorological conditions, yields, and population exposures. For a screening analysis performed in accordance with this AC, an FFBO analysis should state that no individuals will be exposed to a probability of casualty of 1×10^{-5} or greater for neighboring operations personnel, and 1×10^{-6} or greater for other members of the public because every population center within the maximum range of the FFBO hazard is located beyond "no-damage yield" range based on Figure 5 of this AC (replicated from Figure 5.2.3 of the IAASS publication).

8.7 Maximum Expected Casualties.

In accordance with § 450.137(c)(7), a far-field overpressure risk analysis must include the maximum expected casualties that could result from far-field overpressure hazards, given foreseeable meteorological conditions, yields, and population exposures. For a screening analysis performed in accordance with this AC, an FFBO analysis should state that the maximum expected casualties that could result from far-field overpressure hazards in any phase of flight is no more than 1E-6 because every population center within the maximum range of the FFBO hazard is located beyond "no-damage yield" range based on Figure 5 of this AC (replicated from Figure 5.2.3 of the IAASS publication).

8.8 Meteorological Measurements.

In accordance with § 450.137(c)(8), a far-field overpressure risk analysis must include a description of the meteorological measurements used. For a screening analysis performed in accordance with this AC, an FFBO analysis should state no meteorological measurements will be used because every population center within the maximum range of the FFBO hazard is located beyond "no-damage yield" range based on Figure 5 of this AC (replicated from Figure 5.2.3 of the IAASS publication).

Appendix A Yield Factor Equation Coefficients for HD 1.3 Solid Propellants

Table 3 – TNT Yield Equations for Solid Propellant Geometries with Constant Web Thickness to Length Ratios, Side-on Impact in Sand[10]

		Coefficients					Limits (ft/sec)	
Element Type	**Curve**	**a**	**b**	**c**	**d**	**e**	**Min**	**Max**
41-inch Segment	Imp.	-9.67E-14	1.74E-10	-1.02E-07	5.71E-05	3.32E-02	23	800
	OP	3.77E-14	-7.84E-11	6.51E-08	2.23E-05	3.47E-02	23	800
60-inch Segment	Imp	4.97E-13	-7.54E-10	3.98E-07	-3.89E-05	5.49E-02	68	800
	OP	6.36E-13	-9.37E-10	4.81E-07	-4.09E-05	5.73E-02	68	800
92-inch Segment	Imp	-2.03E-13	5.22E-10	-2.20E-07	8.05E-05	7.34E-02	82	800
	OP	-3.79E-13	8.87E-10	-3.91E-07	1.23E-04	8.02E-02	82	800
124-inch Segment	Imp	-4.19E-12	6.66E-09	-3.05E-06	5.50E-04	7.50E-02	83	800
	OP	-5.58E-12	8.85E-09	-4.05E-06	7.35E-04	8.16E-02	83	800
146-inch Segment	Imp	-5.43E-12	7.24E-09	-2.41E-06	3.46E-04	1.08E-01	74	800
	OP	-6.86E-12	9.08E-09	-2.97E-06	4.36E-04	1.25E-01	74	800
41-inch CAS	Imp	-4.31E-13	9.54E-10	-6.82E-07	1.98E-04	9.52E-03	156	1000
	OP	-4.79E-13	1.05E-09	-7.29E-07	2.05E-04	4.61E-03	156	1000
60-inch CAS	Imp	1.87E-14	7.06E-11	-6.74E-08	2.71E-05	3.29E-02	37	800
	OP	4.61E-14	5.87E-11	-6.71E-08	2.95E-05	3.04E-02	37	800
92-inch CAS	Imp	-1.51E-13	4.06E-10	-3.08E-07	1.17E-04	3.98E-02	99	800
	OP	-6.96E-13	1.41E-09	-9.08E-07	2.62E-04	3.17E-02	99	800
124-inch CAS	Imp	-1.24E-12	2.06E-09	-1.01E-06	2.16E-04	4.99E-02	104	800
	OP	-1.54E-12	2.45E-09	-1.11E-06	2.15E-04	5.79E-02	104	800
146-inch CAS	Imp	-2.06E-12	3.26E-09	-1.48E-06	2.67E-04	6.04E-02	94	800
	OP	-2.70E-12	4.22E-09	-1.86E-06	3.18E-04	6.82E-02	94	800
18-inch Cube	Imp	5.84E-16	-8.73E-12	4.42E-08	-1.20E-05	1.99E-02	89	1600
	OP	5.42E-16	-8.91E-12	5.03E-08	-1.36E-05	1.05E-02	89	1600
24-inch Cube	Imp	9.84E-16	-1.34E-11	5.79E-08	-8.19E-06	2.21E-02	79	1600
	OP	1.34E-15	-1.83E-11	8.01E-08	-1.83E-05	1.60E-02	79	1600
30-inch Cube	Imp	-1.39E-17	-8.98E-12	5.79E-08	-4.41E-06	2.66E-02	72	1600
	OP	6.96E-17	-1.30E-11	8.11E-08	-1.24E-05	2.16E-02	72	1600

[10] Devoid, W. and C. Wass, "Final PIRAT Yield Model for Impacting Solid Propellant, Revision 2", Report No. CSR3-00300-R2, A-P-T Research, Inc. Cocoa Beach, FL, 16 September 2011.

Table 4 – TNT Yield Equations for Solid Propellant Geometries with Variable Web Thickness, Side-on Impact in Sand[11]

Element Type, Web Thickness	Curve	Coefficients a	b	c	d	e	Limits (ft/sec) Min	Max
41-in Seg, 21 in	Imp	0.00E+00	8.55E-11	-9.43E-08	6.48E-05	3.19E-02	78	800
	OP	0.00E+00	1.38E-10	-1.47E-07	8.80E-05	2.90E-02	78	800
41-in Seg, 14 in	Imp	0.00E+00	8.04E-11	-8.67E-08	6.11E-05	3.06E-02	76	800
	OP	0.00E+00	1.00E-10	-1.02E-07	7.34E-05	2.71E-02	76	800
41-in Seg, 7 in	Imp	0.00E+00	7.98E-11	-8.23E-08	5.69E-05	2.78E-02	74	800
	OP	0.00E+00	1.03E-10	-9.82E-08	6.72E-05	2.29E-02	74	800
60-in Seg, 30.6 in	Imp	0.00E+00	6.76E-11	-3.87E-08	5.16E-05	4.81E-02	79	800
	OP	0.00E+00	7.23E-11	-2.41E-08	5.71E-05	4.99E-02	79	800
60-in Seg, 20.4 in	Imp	0.00E+00	6.07E-11	-2.84E-08	4.71E-05	4.64E-02	79	800
	OP	0.00E+00	8.25E-11	-3.28E-08	5.78E-05	4.71E-02	79	800
60-in Seg, 10.2 in	Imp	0.00E+00	6.53E-11	-3.05E-08	4.53E-05	4.26E-02	79	800
	OP	0.00E+00	8.96E-11	-4.14E-08	6.13E-05	4.09E-02	79	800
92-in Seg, 47 in	Imp	0.00E+00	1.96E-10	-9.99E-08	6.74E-05	7.27E-02	67	800
	OP	0.00E+00	3.15E-10	-2.00E-07	1.12E-04	7.79E-02	67	800
92-in Seg, 31.3 in	Imp	0.00E+00	1.96E-10	-1.00E-07	6.74E-05	6.99E-02	67	800
	OP	0.00E+00	1.93E-10	-4.52E-08	6.21E-05	7.84E-02	67	800
92-in Seg, 15.6 in	Imp	0.00E+00	2.18E-10	-1.23E-07	7.30E-05	6.41E-02	67	800
	OP	0.00E+00	2.76E-10	-1.42E-07	8.94E-05	6.87E-02	67	800
124-in Seg, 63.2 in	Imp	0.00E+00	5.19E-10	-3.28E-07	1.30E-04	9.11E-02	83	800
	OP	0.00E+00	5.79E-10	-2.84E-07	1.19E-04	1.10E-01	83	800
124-in Seg, 42.2 in	Imp	0.00E+00	5.45E-10	-3.46E-07	1.30E-04	8.92E-02	83	800
	OP	0.00E+00	6.90E-10	-3.98E-07	1.50E-04	1.04E-01	83	800
124-in Seg, 21 in	Imp	0.00E+00	5.29E-10	-3.11E-07	1.14E-04	8.50E-02	83	800
	OP	0.00E+00	6.66E-10	-3.71E-07	1.40E-04	9.54E-02	83	800
146-in Seg, 74.5 in	Imp	0.00E+00	2.17E-11	9.72E-08	2.05E-04	8.29E-02	75	800
	OP	0.00E+00	7.37E-11	9.84E-08	2.64E-04	9.94E-02	75	800
146-in Seg, 49.6 in	Imp	0.00E+00	-7.13E-10	1.10E-06	-1.73E-04	1.19E-01	74	800
	OP	0.00E+00	-8.61E-10	1.37E-06	-2.12E-04	1.44E-01	74	800
146-in Seg, 24.8 in	Imp	0.00E+00	-6.99E-10	1.10E-06	-1.79E-04	1.16E-01	74	800
	OP	0.00E+00	-1.06E-09	1.62E-06	-2.91E-04	1.40E-01	74	800

Table 5 – TNT Yield Equations for Solid Propellant Geometries with Variable Lengths, Side-on Impact in Sand[12]

Element Type, Length	Curve	a	b	c	d	e	Limits (ft/sec) Min	Max
41-in Seg, 66 in	Imp	0.00E+00	1.80E-10	-2.31E-07	1.12E-04	1.84E-02	60	800
	OP	0.00E+00	1.26E-10	-1.51E-07	8.91E-05	1.66E-02	60	800
41-in Seg, 197 in	Imp	0.00E+00	9.64E-11	-1.18E-07	7.32E-05	3.69E-02	67	800
	OP	0.00E+00	1.38E-10	-1.64E-07	9.66E-05	3.51E-02	67	800
41-in Seg, 262 in	Imp	0.00E+00	5.83E-11	-7.41E-08	6.12E-05	4.15E-02	51	800
	OP	0.00E+00	5.31E-11	-6.19E-08	6.57E-05	4.22E-02	51	800
41-in Seg, 327 in	Imp	0.00E+00	1.02E-10	-1.32E-07	8.19E-05	4.19E-02	66	800
	OP	0.00E+00	1.20E-10	-1.53E-07	1.01E-04	4.18E-02	66	800
60-in Seg, 114 in	Imp	0.00E+00	2.47E-11	-1.57E-08	4.77E-05	4.04E-02	67	800
	OP	0.00E+00	5.77E-11	-5.30E-08	7.22E-05	3.87E-02	67	800
60-in Seg, 270 in	Imp	0.00E+00	3.05E-11	-1.25E-08	4.91E-05	5.48E-02	20	800
	OP	0.00E+00	3.20E-11	-2.25E-09	5.92E-05	5.79E-02	20	800
60-in Seg, 347 in	Imp	0.00E+00	-1.76E-11	4.94E-08	3.07E-05	6.04E-02	90	800
	OP	0.00E+00	-3.11E-11	8.10E-08	3.26E-05	6.57E-02	90	800
60-in Seg, 425 in	Imp	0.00E+00	5.68E-11	-3.84E-08	5.54E-05	6.17E-02	17	800
	OP	0.00E+00	2.60E-11	1.49E-08	5.12E-05	6.75E-02	17	800
92-in Seg, 98 in	Imp	0.00E+00	4.78E-10	-4.82E-07	1.57E-04	4.40E-02	77	800
	OP	0.00E+00	6.46E-10	-6.58E-07	2.15E-04	4.24E-02	77	800
92-in Seg, 147 in	Imp	0.00E+00	1.16E-10	-4.83E-08	6.06E-05	5.82E-02	80	800
	OP	0.00E+00	1.49E-10	-5.93E-08	6.10E-05	6.50E-02	75	800
92-in Seg, 196 in	Imp	0.00E+00	2.03E-10	-7.54E-08	7.49E-05	7.14E-02	75	800

[11] Devoid, W. and C. Wass, "Final PIRAT Yield Model for Impacting Solid Propellant, Revision 2", Report No. CSR3-00300-R2, A-P-T Research, Inc. Cocoa Beach, FL, 16 September 2011.
[12] Devoid, W. and C. Wass, "Final PIRAT Yield Model for Impacting Solid Propellant, Revision 2", Report No. CSR3-00300-R2, A-P-T Research, Inc. Cocoa Beach, FL, 16 September 2011.

Element Type, Length	Curve	a	b	c	d	e	Limits (ft/sec) Min	Max
	OP	0.00E+00	2.16E-10	-1.15E-07	7.66E-05	6.90E-02	72	800
92-in Seg, 245 in	Imp	0.00E+00	3.14E-10	-1.76E-07	1.04E-04	7.61E-02	72	800
	OP	0.00E+00	-4.81E-11	1.24E-07	1.91E-05	7.12E-02	84	800
124-in Seg, 132 in	Imp	0.00E+00	-1.35E-10	2.57E-07	-8.15E-06	8.11E-02	84	800
	OP	0.00E+00	1.42E-10	-1.60E-08	5.16E-05	8.02E-02	91	800
124” Seg, 199 in	Imp	0.00E+00	1.90E-10	-1.71E-08	6.61E-05	8.98E-02	91	800
	OP	0.00E+00	5.29E-10	-3.28E-07	1.27E-04	8.34E-02	85	800
124” Seg, 265 in	Imp	0.00E+00	7.05E-10	-4.17E-07	1.53E-04	9.59E-02	85	800
	OP	0.00E+00	4.87E-10	-2.93E-07	1.25E-04	8.91E-02	71	800
124” Seg, 331 in	Imp	0.00E+00	6.81E-10	-4.25E-07	1.73E-04	1.03E-01	71	800
	OP	0.00E+00	1.49E-10	-5.93E-08	6.10E-05	6.50E-02	75	800
146” Seg, 165 in	Imp	0.00E+00	5.74E-11	-3.12E-08	8.80E-05	7.88E-02	72	800
	OP	0.00E+00	1.24E-10	-8.57E-08	1.23E-04	8.91E-02	72	800
146” Seg, 243 in	Imp	0.00E+00	4.36E-10	-2.66E-07	1.29E-04	8.82E-02	75	800
	OP	0.00E+00	5.89E-10	-3.58E-07	1.69E-04	1.03E-01	75	800
146” Seg, 320 in	Imp	0.00E+00	5.34E-10	-3.19E-07	1.41E-04	9.54E-02	72	800
	OP	0.00E+00	8.78E-10	-6.10E-07	2.36E-04	1.11E-01	72	800
146” Seg, 398 in	Imp	0.00E+00	6.25E-10	-3.79E-07	1.56E-04	1.00E-01	75	800
	OP	0.00E+00	7.91E-10	-4.54E-07	1.91E-04	1.21E-01	75	800

OMB Control Number: 2120-0746
Expiration Date: 11/30/2024

Advisory Circular Feedback Form

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) emailing this form to 9-AST-ASZ210-Directives@faa.gov, or (2) faxing it to (202) 267-5450.

Subject: (insert AC title/number here) Date: Click here to enter text.

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph Click here to enter text. on page Click here to enter text..

☐ Recommend paragraph Click here to enter text. on page Click here to enter text. be changed as follows:

Click here to enter text.

☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

Click here to enter text.

☐ Other comments:

Click here to enter text.

☐ I would like to discuss the above. Please contact me.

Submitted by: ________________________________ Date: _________________________

FAA Form 1320-73 (09/22) SUPERSEDES PREVIOUS EDITIONS