APPENDIX E: ACTIVE AND PASSIVE VEHICLE BARRIER IMPACT RATING DETERMINATION

Barrier Ratings

Two Rating Systems

- DOS STD 02.01
  - ‘K’ rating for kinetic energy capability
  - ‘L’ rating for penetration
  - Example: K12 L2
- ASTM F2656 / F2656M-18a
  - First letter is vehicle code (e.g. M = standard test truck)
  - Number following vehicle code is the tested speed in MPH
  - ‘P’ rating for penetration
  - Example: M50 P3

DOS/DoD: Barrier Ratings

- **K4 = 15,000# @ 30 mph = 450,900 ft-lbs**
- **K8 = 15,000# @ 40 mph = 801,600 ft-lbs**
- **K12 = 15,000# @ 50 mph = 1,252,500 ft-lbs**

- **(DoD Only) L = Penetration of vehicle beyond the barrier**
  - **L1 = 20 to 50 feet**
  - **L2 = 3 to 20 feet**
  - **L3 = less than 3 feet**

Comparison of ASTM to DOS

ASTM F 2656-15

- M30 = 15,000# @ 30 mph
- M40 = 15,000# @ 40 mph
- M50 = 15,000# @ 50 mph

- P1 = <1 m (3.3 ft)
- P2 = 1.01 to 7 m (3.31 to 23.0 ft)
- P3 = 7.01 to 30 m (23.1 to 98.4 ft)

Department of State

- K4 = 15,000# @ 30 mph
- K8 = 15,000# @ 40 mph
- K12 = 15,000# @ 50 mph

- L3 = 3 ft (915 mm) or less
- L2 = 3 ft to 20 ft (915 mm to 6.1 m)
- L1 = 20 ft to 50 ft (6.1 m to 15.3 m)

Barrier Kinetic Energy Capability

To determine the kinetic energy produced by a threat vehicle impacting a barrier, the following need to be calculated:

- Speed achievable at impact (limited by max. velocity of 130mph per UFC 4-022-01 OR spin out speed)

- Maximum Angle achievable at impact (spin out speed becomes a factor)

This applies to both Active Vehicle and Passive Vehicle barriers

Kinetic Energy Equations

From *UFC 4-022-02, Selection and Application of Vehicle Barriers*

US units: $KE = 0.0334w\,(v \times \sin\vartheta)^2$

Where:

$KE = \text{Kinetic Energy (ft–lbs)}$
$w = \text{Weight of vehicle (lbs)}$
$v = \text{Velocity of vehicle (mph)}$
$\vartheta = \text{Impact angle (degrees)}$

If the impact angle between the barrier and the vehicle is 90º, than $\sin\vartheta = 1$, the equation becomes:

$$KE = 0.0334wv^2$$

Active Vehicle Barrier Example

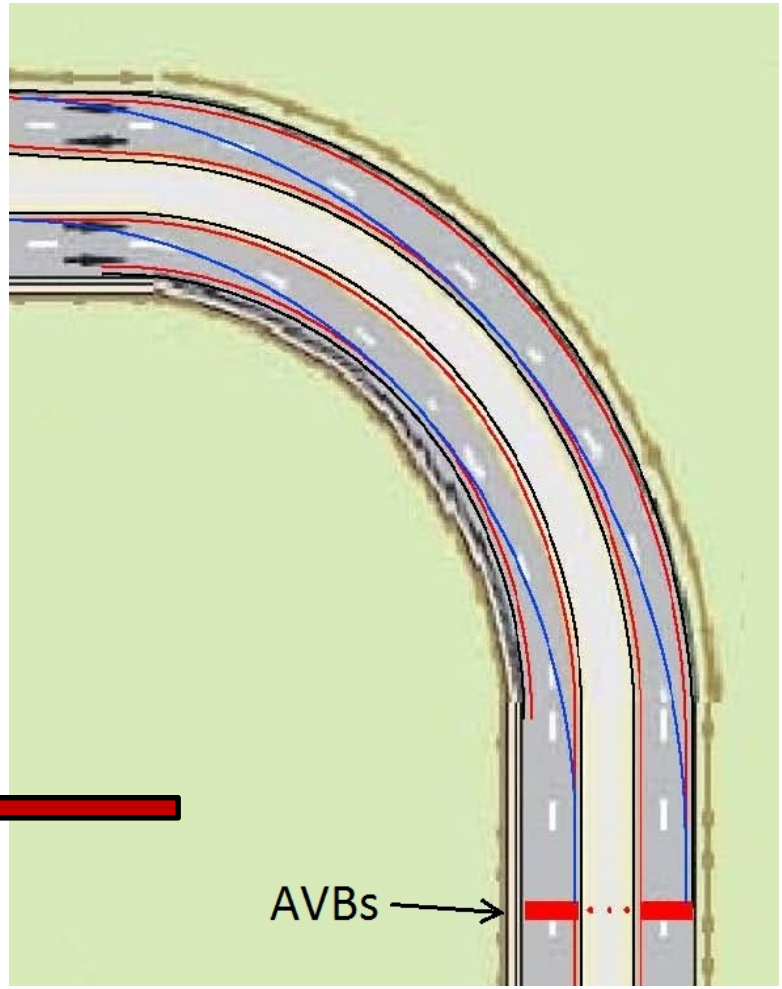
- Baseline Threat Vehicle: 4630 lb sedan
- Impact Velocity at:
  - Inbound AVB = 54.9 mph
  - Outbound AVB = 59.7 mph

- **Worst case is a 90 degree impact**

$$KE = 0.0334wv^2$$

$$KE_{Inbound} = 0.0334 \times 4630lbs \times 54.9^2 mph$$
$$= 466{,}000\ ft\text{–}lbs$$

$$KE_{Outbound} = 0.0334 \times 4630lbs \times 59.7^2 mph$$
$$= 551{,}000\ ft\text{–}lbs$$



Select DOS/DoD Barrier

- K4 – 15,000# @ 30 mph = 450,900 ft-lbs
- K8 – 15,000# @ 40 mph = 801,600 ft-lbs
- K12 – 15,000# @ 50 mph = 1,252,500 ft-lbs

$$KE_{Inbound} = 466{,}000 \text{ ft–lbs}$$
$$KE_{Outbound} = 551{,}000 \text{ ft–lbs}$$

ASTM Barrier by Kinetic Energy

F2656/F2656M – 15

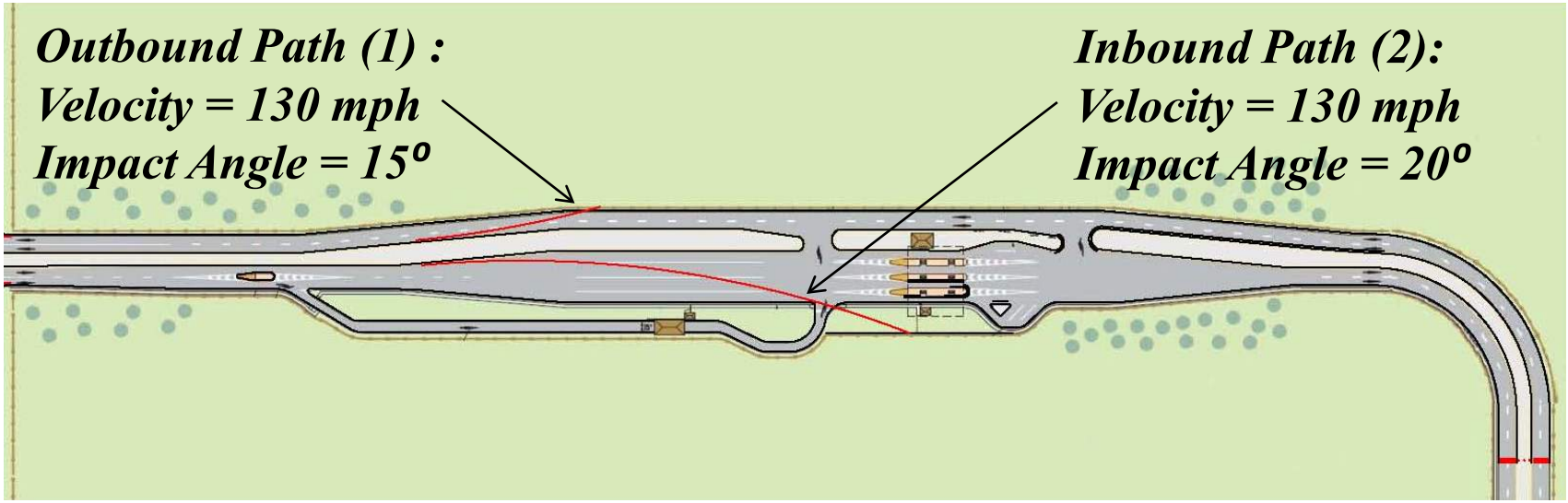
TABLE 1 Impact Condition Designations

Test Vehicle/Minimum Test Inertial Vehicle, kg [lbm]	Nominal Minimum Test Velocity, km/h [mph]	Permissible Speed Range, km/h [mph]	Kinetic Energy, KJ [ft-kips]	Condition Designation
Small passenger car (SC) 1100 [2430] 1100 + 25 [2420 + 55]	50 [30]	45.0-60.0 [28.0-37.9]	106 [78]	SC30
	65 [40]	60.1-75.0 [38.0-46.9]	179 [131]	SC40
	80 [50]	75.1-90.0 [47.0-56.9]	271 [205]	SC50
	100 [60]	90.1- above [57.0-above]	424 [295]	SC60
Full-size Sedan (FS) 2100 [4630] 2100 + 50 [4630 + 110]	50 [30]	45.0-60.0 [28.0-37.9]	203 [37]	FS30
	65 [40]	60.1-75.0 [38.0-46.9]	342 [247]	FS40
	80 [50]	75.1-90.0 [47.0-56.9]	519 [387]	FS50
	100 [60]	90.1-above [57.0-above]	810 [557]	FS60
Pickup truck (PU) 2300 [5070]	50 [30]	45.0-60.0 [28.0-37.9]	222 [164]	PU30
	65 [40]	60.1-75.0 [38.0-46.9]	375 [273]	PU40
	80 [50]	75.1-90.0 [47.0-56.9]	568 [426]	PU50
	100 [60]	90.1- above [57.0-above]	887 [613]	PU60
Standard Test Truck (M) 6800 [15 000] 11 800-14 970 [26 000-33 000]	50 [30]	45.0-60.0 [28.0-37.9]	[illegible]	[illegible]
	65 [40]	60.1-75.0 [38.0-46.9]	1110 [802]	M40
	80 [50]	75.1-above [47.0-above]	1680 [1250]	M50
			673 [497]	C730
			1199 [884]	C740
			1872 [1381]	C750
			2850 [1950]	H30
			4810 [3470]	H40
	[illegible] [30]	75.1-above [47.0-above]	7280 [5430]	H50

$KE_{Inbound} = 466{,}000$ ft–lbs

$KE_{Outbound} = 551{,}000$ ft–lbs

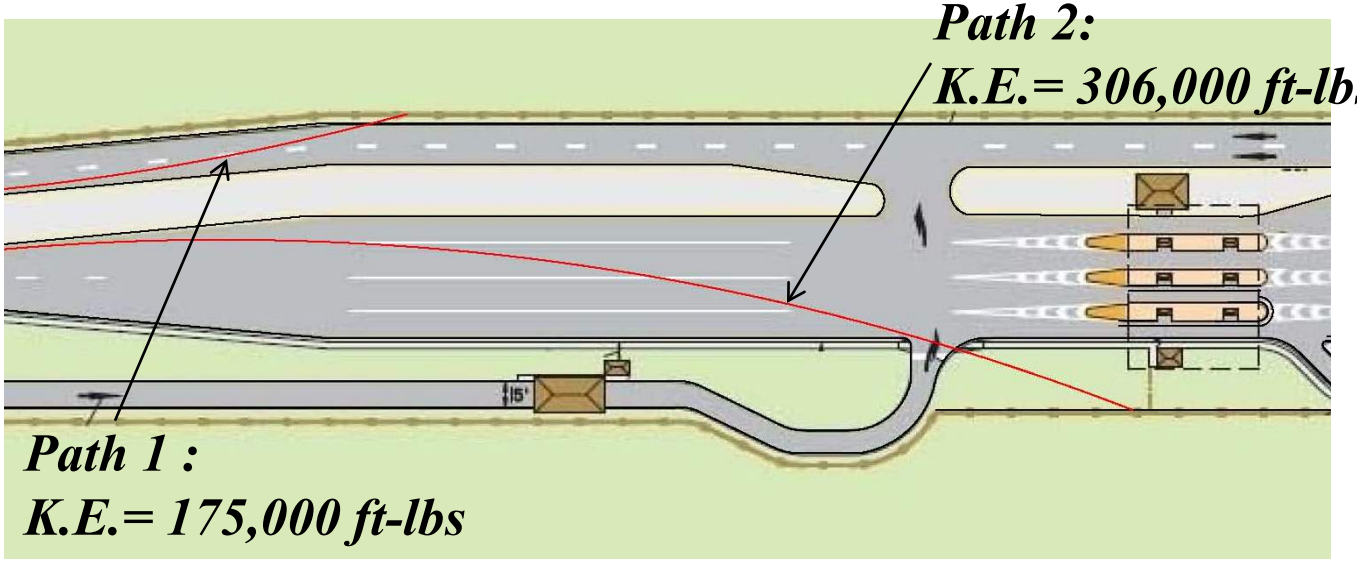
Passive Barrier Design



The following steps illustrate the typical procedure for determining the required impact rating for Passive Vehicle Barriers.

1. Establish a baseline for a typical passive vehicle barrier segment in the ACP corridor. Select a path in both the Inbound and Outbound lanes with a large radius of curvature (greater than 1129', which corresponds to the spin out speed for the 130 mph max. velocity) and shallow impact angle. The ideal baseline will result in the Threat Vehicle not reducing speed to keep from spinning prior to impacting the passive vehicle barrier.

Passive Barrier Design

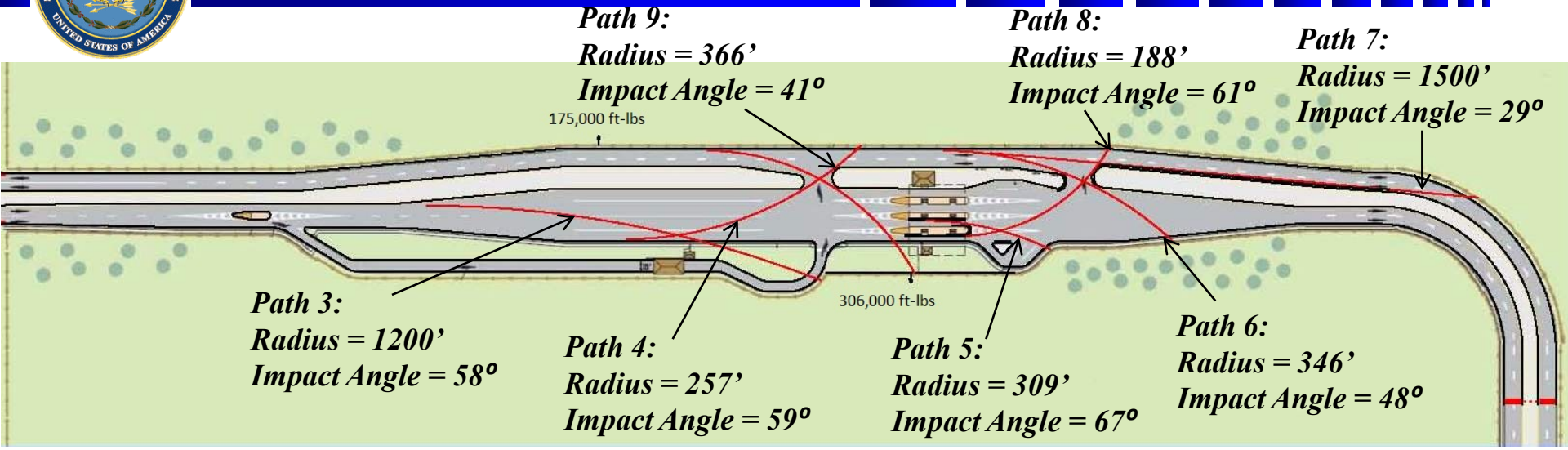


2. Use the following formula to determine the Kinetic Energy for these locations:

$$KE = 0.0334w\,(v \times \sin\vartheta)^2$$

(The calculated KE values are shown on the drawing)

Passive Barrier Design



3. Find the non-typical locations where the angle of impact could be greater. In this example seven additional locations and the corresponding paths (3-0) are shown. Measure the impact angle and path radii.

Once again, use the following equation to determine the Kinetic Energy:

$$KE = 0.0334w\,(v \times \sin\vartheta)^2$$

Some of the additional paths have a radii smaller than 1129', therefore, spin out speed will need to be calculated to determine "v" in the KE equation.

Passive Barrier Design

4. Calculation of spin out speed:

From *UFC 4-022-02, Selection and Application of Vehicle Barriers*

US Units: $\mathbf{V_s} = \sqrt{fgr}$

Where: **Vs** = spin out speed, ft/sec

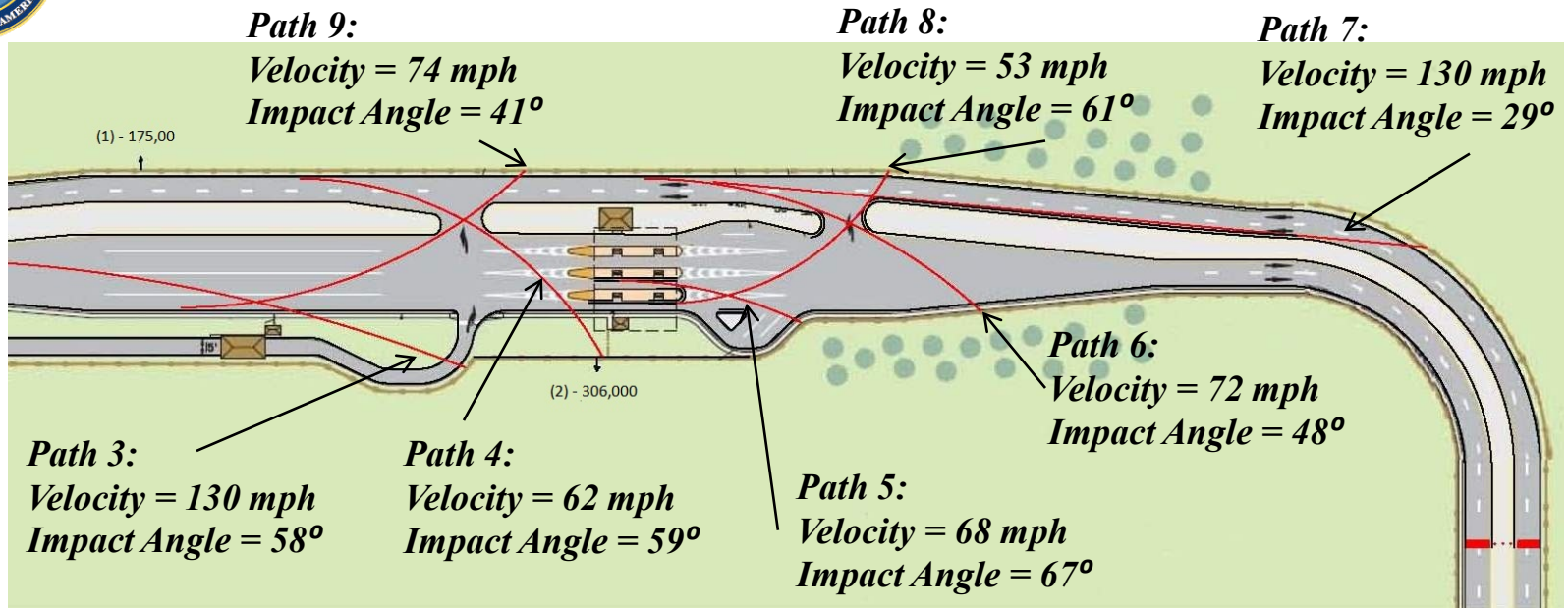
f = friction coefficient (1.0 per UFC 4-022-01)

g = gravitational constant = 32.2 ft/sec^2

r = radius of curvature, ft

5. Convert V_s from ft/sec to mph before using it in the Kinetic Energy equation (1 mph = 1.467 ft/s). Substitute V_s for "v" in the KE equation.

Passive Barrier Design



6. Calculated Kinetic Energy for each path:

Path 3 = 1,880,000 ft-lbs
Path 4 = 437,000 ft-lbs
Path 5 = 606,000 ft-lbs
Path 6 = 443,000 ft-lbs
Path 7 = 614,000 ft-lbs
Path 8 = 332,000 ft-lbs
Path 9 = 364,000 ft-lbs

Passive Barrier Design

7. Determine a DoD/DoS barrier to be used:

1: 175,000 ft-lbs - *K4*
2: 306,000 ft-lbs - *K4*
3: 1,880,000 ft-lbs - *K12*
4: 437,000 ft-lbs - *K4*
5: 606,000 ft-lbs - *K8*
6: 443,000 ft-lbs - *K4*
7: 614,000 ft-lbs - *K8*
8: 332,000 ft-lbs - *K4*
9: 364,000 ft-lbs - *K4*

DoD/DoS tested;

- ***K4 = 450,900 ft-lbs***
- ***K8 = 801,600 ft-lbs***
- ***K12 = 1,252,500 ft-lbs***

Army Standard for ACPs:

(Passive Vehicle Barriers) Are not required to exceed 1,200,000 ft-lbs of Kinetic Energy…..
Unless Threat vehicle in excess of 15,000 lbs is identified in "local" threat assessment/policy

Passive Barrier Design

8. Determine an ASTM F 2656-07 barrier to be used:

1: 175,000 ft-lbs – PU50, M30
2: 306,000 ft-lbs – PU50, M30
3: 1,880,000 ft-lbs – M50
4: 437,000 ft-lbs – M30, PU60
5: 606,000 ft-lbs – PU60, M40
6: 443,000 ft-lbs – M30, PU60
7: 614,000 ft-lbs – M40
8: 332,000 ft-lbs – PU50, M30
9: 364,000 ft-lbs – PU50, M30

F 2656 – 07

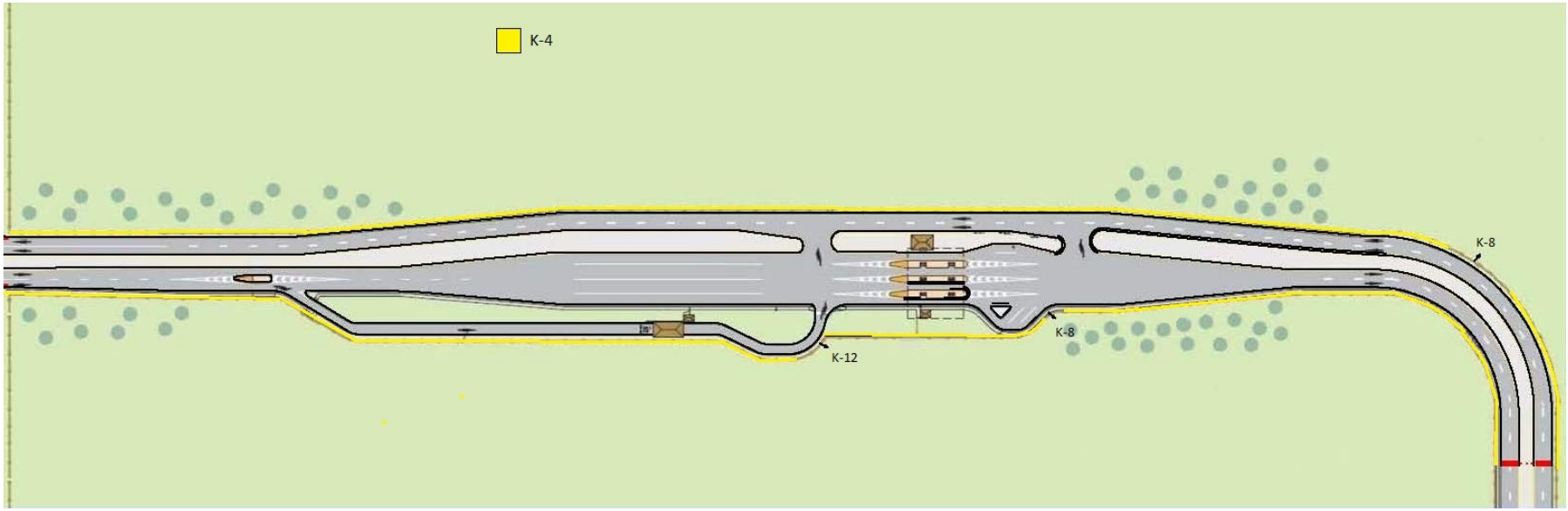
TABLE 1 Impact Condition Designations

Test Vehicle/Minimum Test Inertial Vehicle, kg (lbm)	Kinetic Energy, KJ (ft-kips)	Condition Designation
Small passenger car (C) 1100 (2430)	179 (131)	C40
	271 (205)	C50
	424 (295)	C60
Pickup truck (P) 2300 (5070)	375 (273)	PU40
	568 (426)	PU50
	887 (613)	PU60
Medium-duty truck (M) 6800 (15 000)	656 (451)	M30
	1110 (802)	M40
		M50
		H30
		H40
		H50

r complete chart

Due to the small number of barriers rated for pick-up trucks and having locations where the pick-up truck rating does not meet the required Kinetic Energy, recommend using the barriers rated for a Medium-duty Truck (M rating). Not only will this reduce the number of different barriers being used but these match the K ratings from the DoS standard.

Passive Barrier Design



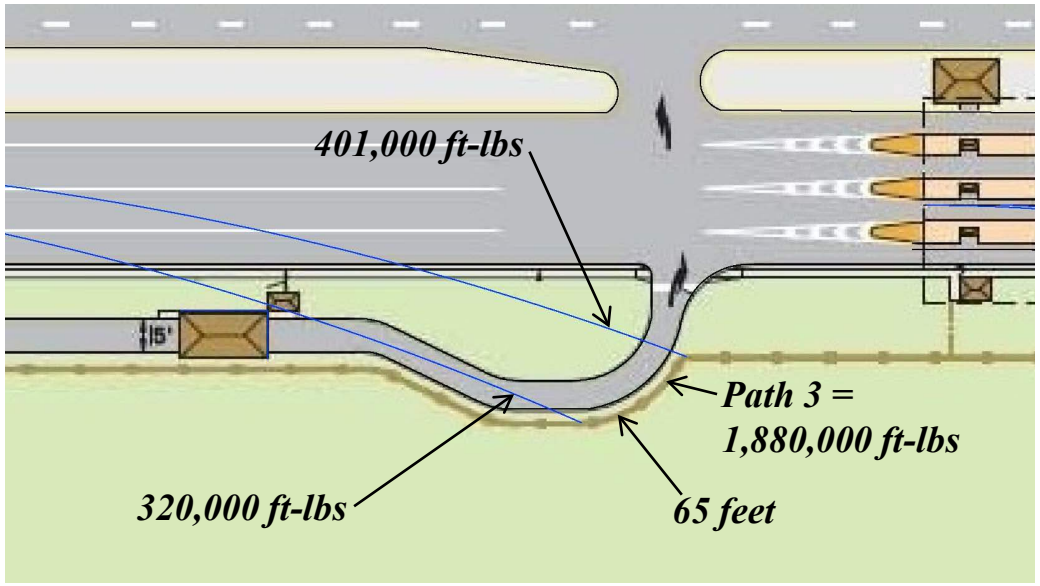
9. To reduce cost, use the lowest-rated barrier to encompass as much of the ACP corridor as possible, and use the higher-rated barrier only where required.

Use the Kinetic Energy equation and the geometric layout of the ACP to determine the required length and location of the higher-rated barriers.

Draw additional paths where the passive vehicle barrier changes in alignment and calculate the Kinetic Energy. The following slides illustrate a conservative solution for the extents of the higher-rated barrier.

Passive Barrier Design

Determining length of higher-rated barrier:
The calculated Kinetic Energy of the additional paths are shown, in addition to the worst-case path from step 3 for the given PVB segment.

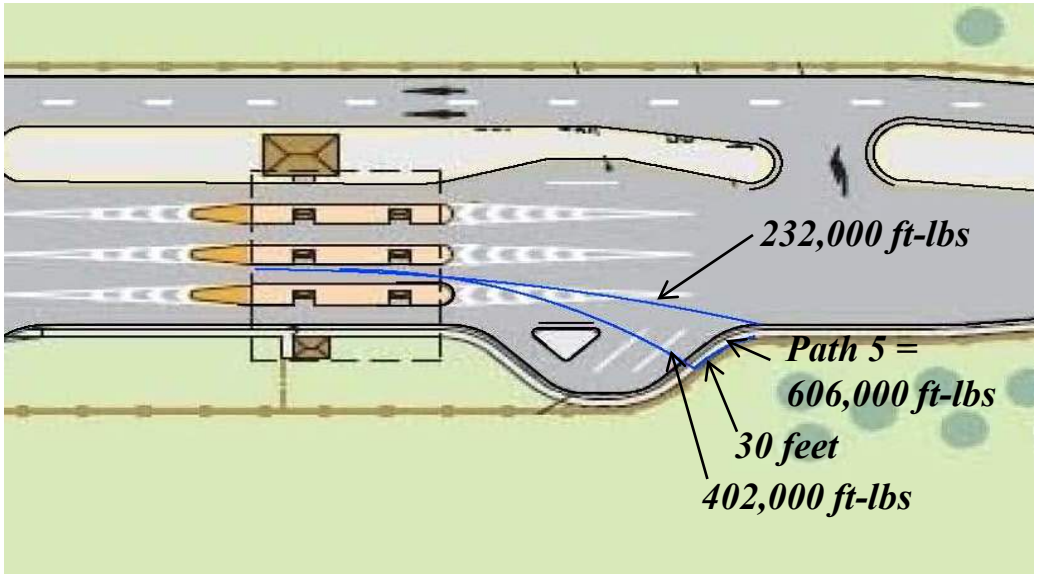


Barrier by Search Area:

- 65’ of K12 (M50) barrier

Passive Barrier Design

Determining length of higher-rated barrier

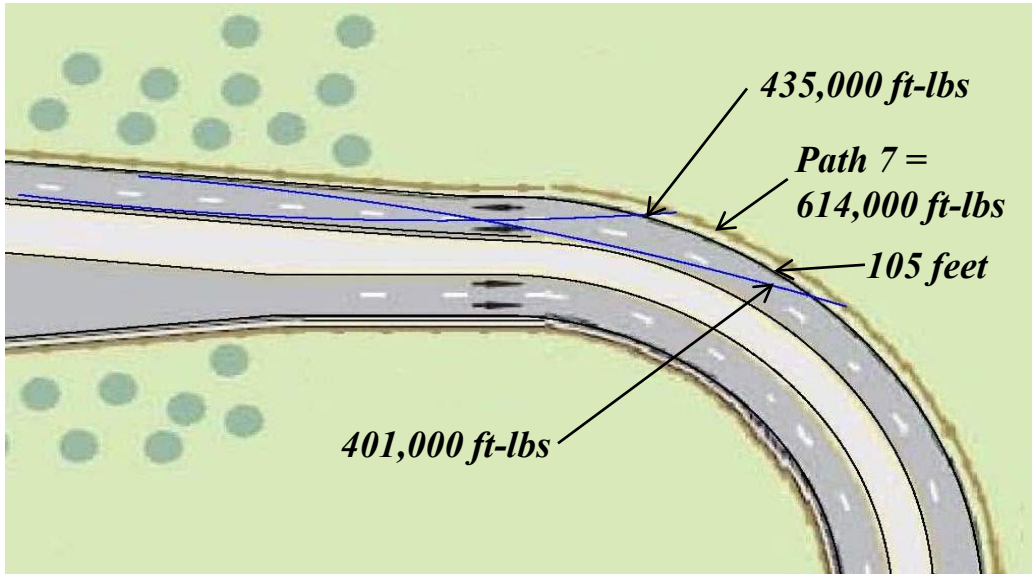


Barrier by ID Check Area:

- 30’ of K8 (M40) barrier

Passive Barrier Design

Determining length of higher-rated barrier

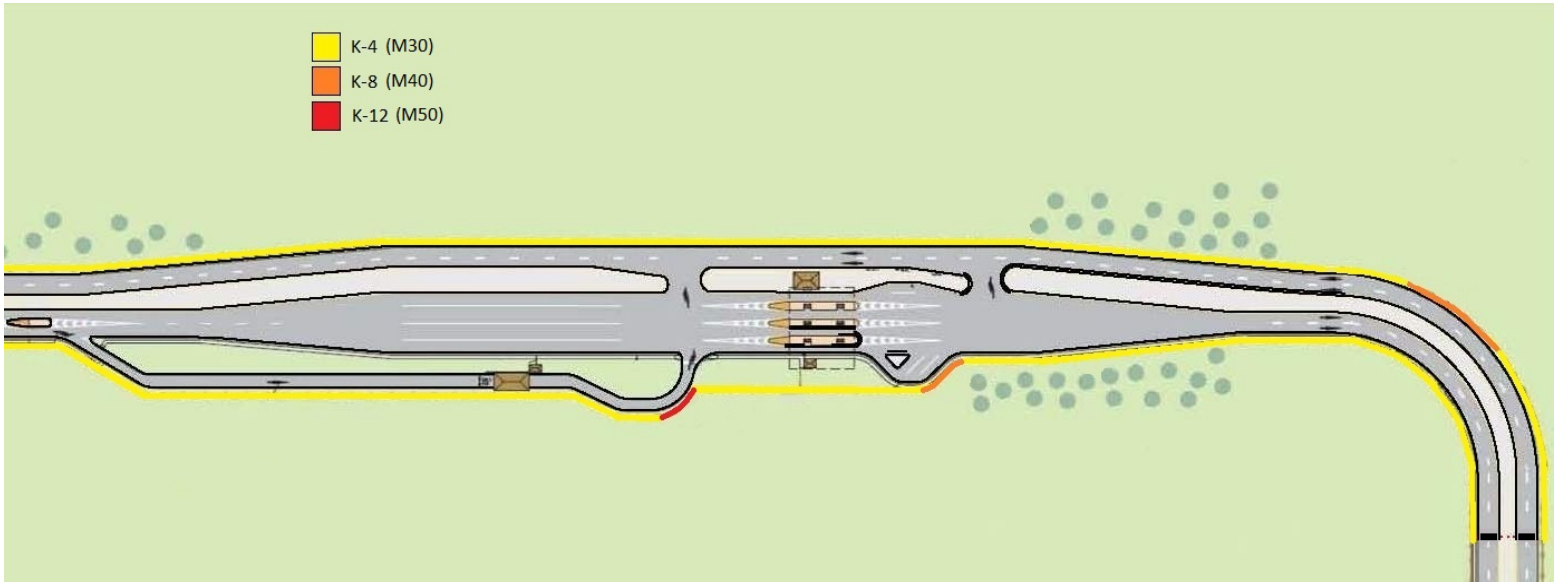


Barrier at Curve:

- 105’ of K8 (M40) barrier

Passive Barrier Design

Color-coded barrier layout



Total lengths of Passive Vehicle Barrier:

4500 LF of K4 (M30) rated barrier

135 LF of K8 (M40) rated barrier

65 LF of K12 (M50) rated barrier

Passive Barrier Design

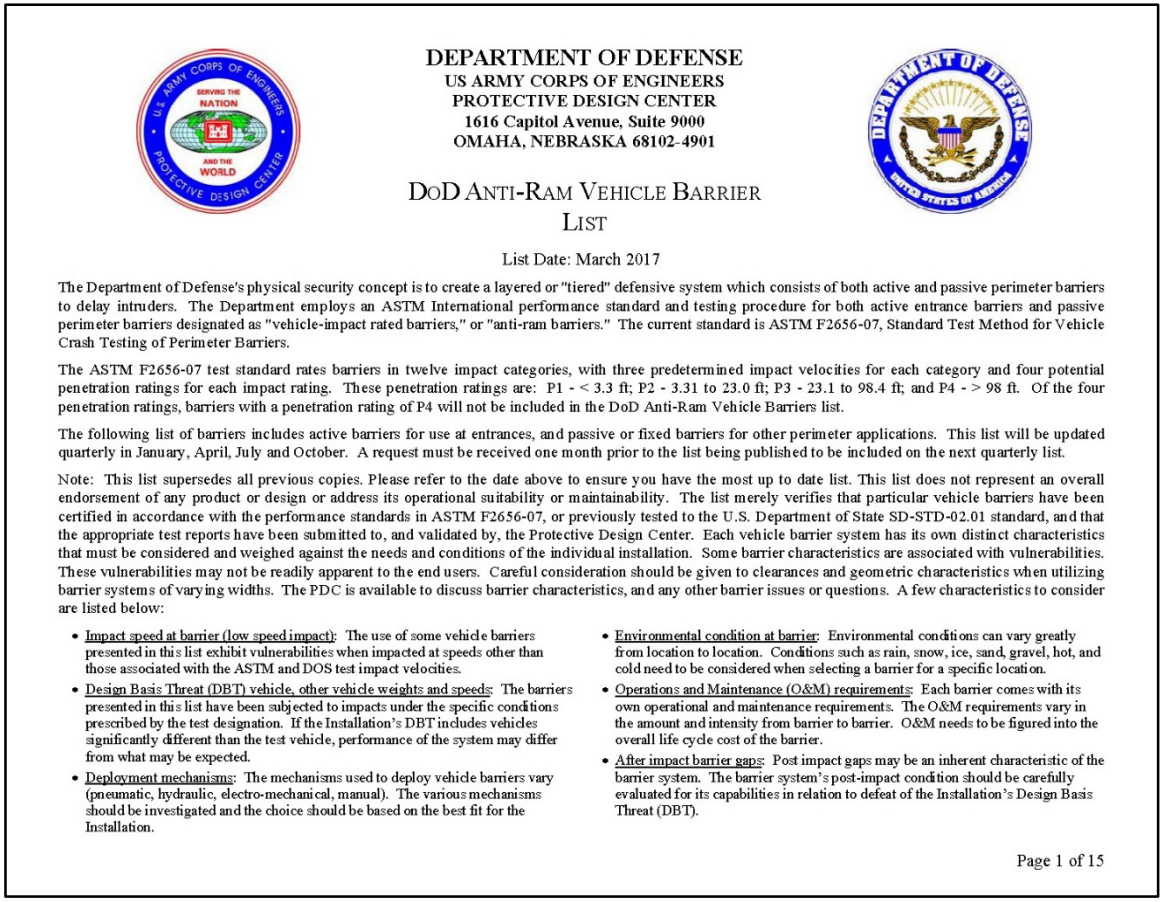
NOTE: The barrier rating determined from the calculated impact Kinetic Energy represent the MINIMUM required impact rating. A impact rating higher than what is required is acceptable.

It may be impractical and more costly to construct short segments of lower-rated barrier within a longer segment of higher-rated barrier. In this situation, a continuous segment of the higher-rated barrier would be easier to construct and eliminate what could be complex transitions between barriers of different ratings.

Vehicle Barriers for DoD Use

10. Select Barrier from DoD Anti-Ram Vehicle Barrier List

- For typical ACP design projects, the construction contractor will select the barrier that meets the required impact rating and the project specifications.



DEPARTMENT OF DEFENSE
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DoD Anti-Ram Vehicle Barrier List

List Date: March 2017

The Department of Defense's physical security concept is to create a layered or "tiered" defensive system which consists of both active and passive perimeter barriers to delay intruders. The Department employs an ASTM International performance standard and testing procedure for both active entrance barriers and passive perimeter barriers designated as "vehicle-impact rated barriers," or "anti-ram barriers." The current standard is ASTM F2656-07, Standard Test Method for Vehicle Crash Testing of Perimeter Barriers.

The ASTM F2656-07 test standard rates barriers in twelve impact categories, with three predetermined impact velocities for each category and four potential penetration ratings for each impact rating. These penetration ratings are: P1 - < 3.3 ft; P2 - 3.31 to 23.0 ft; P3 - 23.1 to 98.4 ft; and P4 - > 98 ft. Of the four penetration ratings, barriers with a penetration rating of P4 will not be included in the DoD Anti-Ram Vehicle Barriers list.

The following list of barriers includes active barriers for use at entrances, and passive or fixed barriers for other perimeter applications. This list will be updated quarterly in January, April, July and October. A request must be received one month prior to the list being published to be included on the next quarterly list.

Note: This list supersedes all previous copies. Please refer to the date above to ensure you have the most up to date list. This list does not represent an overall endorsement of any product or design or address its operational suitability or maintainability. The list merely verifies that particular vehicle barriers have been certified in accordance with the performance standards in ASTM F2656-07, or previously tested to the U.S. Department of State SD-STD-02.01 standard, and that the appropriate test reports have been submitted to, and validated by, the Protective Design Center. Each vehicle barrier system has its own distinct characteristics that must be considered and weighed against the needs and conditions of the individual installation. Some barrier characteristics are associated with vulnerabilities. These vulnerabilities may not be readily apparent to the end users. Careful consideration should be given to clearances and geometric characteristics when utilizing barrier systems of varying widths. The PDC is available to discuss barrier characteristics, and any other barrier issues or questions. A few characteristics to consider are listed below:

- Impact speed at barrier (low speed impact): The use of some vehicle barriers presented in this list exhibit vulnerabilities when impacted at speeds other than those associated with the ASTM and DOS test impact velocities.
- Design Basis Threat (DBT) vehicle, other vehicle weights and speeds: The barriers presented in this list have been subjected to impacts under the specific conditions prescribed by the test designation. If the Installation's DBT includes vehicles significantly different than the test vehicle, performance of the system may differ from what may be expected.
- Deployment mechanisms: The mechanisms used to deploy vehicle barriers vary (pneumatic, hydraulic, electro-mechanical, manual). The various mechanisms should be investigated and the choice should be based on the best fit for the Installation.
- Environmental condition at barrier: Environmental conditions can vary greatly from location to location. Conditions such as rain, snow, ice, sand, gravel, hot, and cold need to be considered when selecting a barrier for a specific location.
- Operations and Maintenance (O&M) requirements: Each barrier comes with its own operational and maintenance requirements. The O&M requirements vary in the amount and intensity from barrier to barrier. O&M needs to be figured into the overall life cycle cost of the barrier.
- After impact barrier gaps: Post impact gaps may be an inherent characteristic of the barrier system. The barrier system's post-impact condition should be carefully evaluated for its capabilities in relation to defeat of the Installation's Design Basis Threat (DBT).

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https://pdc.usace.army.mil/library/BarrierCertification/