



Publications Transmittal

| | |
|--|--------------------|
| Transmittal Number | Date |
| PT 11-064 | August 2011 |
| Publication Distribution | |
| To: Design Manual holders | |
| Publication Title | Publication Number |
| Design Manual Supplement – August 2011 | M 22-01 |
| Originating Organization | |
| WSDOT Design Office, Design Policy, Standards, and Safety Research Section | |

Remarks/Instruction

This *Design Manual* Chapter 1620 Supplement is to revise WSDOT policy relating to the selection of impact attenuator systems.

If you maintain a printed manual, please remove the current Chapter 1620 and replace it with the August 2011 Supplement.

To get the latest information on WSDOT administrative and engineering manuals, sign up for e-mail updates for individual manuals at: <http://www.wsdot.wa.gov/publications/manuals/>

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Washington State Department of Transportation
Design Manual Supplements and Instructional Letters

August, 2011

Note: To make your *Design Manual* complete, you must have the Supplements and Instructional Letters that are currently in effect.

Design Manual Supplements and Instructional Letters are issued as interim guidance until they are incorporated into the *Design Manual*.

| Subject/Title | Impacted Chapter(s) | Effective Date | Document Type |
|---------------------------|----------------------------|-----------------------|----------------------|
| Impact Attenuator Systems | 1620 | 8/2011 | Supplement |

The *Design Manual* is available online through the Publications Services website, where you can also download individual chapter files, known technical errata, and *Design Manual* Supplements:

↗ www.wsdot.wa.gov/Publications/Manuals/index.htm



/s/ Pasco Bakotich III

State Design Engineer

Effective Date: August 2011

Impact Attenuator System Selection

I. Introduction

A. Purpose

The purpose of this *Design Manual* Supplement is to revise Washington State Department of Transportation (WSDOT) policy relating to the selection of impact attenuator systems.

B. References

None.

C. Background

Design Manual Chapter 1620, section 1620.03, currently provides guidance on selecting an impact attenuator system for a given application/location. The choice of an appropriate device varies depending on site criteria. For example, if few impacts are anticipated, lower-cost devices such as inertial barriers might meet the need. In contrast, in situations where at least one impact is anticipated per year, designers are directed to limit the selection of impact attenuators to low-maintenance devices. Currently, the QuadGuard Elite and REACT 350 are considered to be low-maintenance devices.

D. Discussion

Although the current policy direction provided in *Design Manual* Chapter 1620, section 1620.03, provides selection guidance, unfortunately that guidance lacks direction on the consideration of criteria such as average daily traffic (ADT), proximity to the roadway, maintenance crew repair time, crew exposure time, and so on. This *Design Manual* Supplement considers the input of WSDOT maintenance personnel and other sources, and it expands the selection criteria so it is related to measurable site conditions. This new policy expands the selection of low-maintenance devices to include the SCI100GM / SCI70GM attenuators, with the intent of satisfying maintenance needs and also creating a more competitive environment among suppliers. In addition, this policy change is intended to offer designers more selection alternatives in choosing a low-maintenance device that best fits a given application.

E. Implementation

This policy is effective immediately and is incorporated in the *Design Manual* available on-line:

↗ <http://www.wsdot.wa.gov/publications/manuals/index.htm>

II. Instructions

A. Insert the Supplement

The Contents and Index sections remain unchanged for this supplement. They will be updated with the next regularly scheduled *Design Manual* revision.

- 1620.01 General
- 1620.02 Design Criteria
- 1620.03 Selection
- 1620.04 Documentation

1620.01 General

Impact attenuator systems are protective systems that help aid an errant vehicle from impacting an object by either gradually decelerating the vehicle to a stop when hit head-on or by redirecting it away from the feature when struck on the side. These barriers are used for rigid objects or other features that cannot be removed, relocated, or made breakaway.

Approved systems are shown in Exhibits 1620-2a through 1620-4b and on the Washington State Department of Transportation (WSDOT) Headquarters (HQ) Design Office web page: www.wsdot.wa.gov/Design/Policy/RoadsideSafety.htm

Approved systems shall meet standardized testing defined in NCHRP Report 350 or the *Manual for Assessing Safety Hardware* (MASH). In addition, these devices shall have an acceptance letter from FHWA that documents that the device meets the appropriate crash test criteria and can be used on the National Highway System (NHS).

(1) Permanent Installations

For systems used in permanent installations, a description of the system's purpose, parts, and function, as well as transition needs, foundation, and slope, are provided as follows and in Exhibit 1620-5.

(a) Crash Cushion Attenuating Terminal (CAT-350)

1. **Purpose:** The CAT-350 is an end treatment for W-beam guardrail. It can also be used for concrete barrier if a transition is provided.
2. **Description:** The system consists of slotted W-beam guardrail mounted on both sides of breakaway timber posts. Steel sleeves with soil plates hold the timber posts in place (see Exhibit 1620-2a).
3. **Function:** When hit head-on, the slotted guardrail is forced over a pin that shears the steel between the slots. This shearing dissipates the energy of the impact.
4. **Foundation:** Concrete footings or foundations are not needed.
5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.

6. Manufacturer/Supplier: Trinity Industries, Inc.

(b) Brakemaster 350

1. **Purpose:** The Brakemaster 350 system is an end treatment for W-beam guardrail. It can also be used for concrete barrier if a transition is provided.
2. **Description:** The system contains an embedded anchor assembly, W-beam fender panels, transition strap, and diaphragm (see Exhibit 1620-2a).

3. **Function:** The system uses a brake and cable device for head-on impacts and for redirection. The cable is embedded in a concrete anchor at the end of the system.
4. **Foundation:** A concrete foundation is not needed for this system, but a paved surface is recommended.
5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.
6. **Manufacturer/Supplier:** Energy Absorption Systems

(c) **QuadTrend 350**

1. **Purpose:** The QuadTrend 350 is an end treatment for 2-foot-8-inch-high concrete barriers. The system's short length allows it to be used at the ends of bridges where the installation of a beam guardrail transition and terminal is not feasible.
2. **Description:** This system consists of telescoping quadruple corrugated fender panels mounted on steel breakaway posts (see Exhibit 1620-2a).
3. **Function:** Sand-filled boxes attached to the posts dissipate a portion of the energy of an impact. An anchored cable installed behind the fender panels directs the vehicle away from the barrier end.
4. **Foundation:** The system is installed on a concrete foundation to support the steel posts.
5. **Slope:** A 6H:1V or flatter slope is needed behind the barrier to allow for vehicle recovery.
6. **Manufacturer/Supplier:** Energy Absorption Systems

(d) **Universal TAU-II**

1. **Purpose:** The Universal TAU-II crash cushion system is an end treatment for concrete barrier, beam guardrail, and fixed objects up to 8 feet wide.
2. **Description:** The system is made up of independent collapsible bays containing energy-absorbing cartridges that are guided and supported during a head-on hit by high-strength galvanized steel cables and thrie beam rail panels. Each bay is composed of overlapping thrie beam panels on the sides and structural support diaphragms on the ends. Structural support diaphragms are attached to two cables running longitudinally through the system and attached to foundations at each end of the system (see Exhibit 1620-2c).
3. **Function:** Overlapping panels, structural support diaphragms, cable supports, cables, and foundation anchors allow the system to resist angled impacts and mitigate head-on impacts.
4. **Foundation:** The system is installed on a concrete foundation or asphaltic concrete foundations conforming to the manufacturer's recommendations.
5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.
6. **Manufacturer/Supplier:** Barrier Systems, Inc.

(e) QuadGuard

1. **Purpose:** The QuadGuard is an end treatment for concrete barrier and beam guardrail and is also used to mitigate fixed objects up to 10 feet wide.
2. **Description:** The system consists of a series of Hex-Foam cartridges surrounded by a framework of steel diaphragms and quadruple corrugated fender panels (see Exhibit 1620-2b).
3. **Function:** The internal shearing of the cartridges and the crushing of the energy absorption material absorb impact energy from end-on hits. The fender panels redirect vehicles impacting the attenuator on the side.
4. **Foundation:** The system is installed on a concrete foundation.
5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is needed. "Excessive" is defined as steeper than 8% for the QuadGuard.
6. **Manufacturer/Supplier:** Energy Absorption Systems

(f) QuadGuard Elite

1. **Purpose:** The QuadGuard Elite is an end treatment for concrete barrier and beam guardrail and is also used for fixed objects up to 7 feet 6 inches wide.
2. **Description:** The system consists of telescoping quadruple corrugated fender panels mounted on both sides of a series of polyethylene cylinders (see Exhibit 1620-2b).
3. **Function:** The cylinders are compressed during a head-on impact and return to their original shape when the system is reset. It is anticipated that this system will need very few replacement parts or extensive repair.
4. **Foundation:** The system is installed on a concrete foundation.
5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is needed. "Excessive" is defined as steeper than 8% for the QuadGuard Elite.
6. **Manufacturer/Supplier:** Energy Absorption Systems

(g) Reusable Energy Absorbing Crash Terminal (REACT 350)

1. **Purpose:** The REACT 350 is an end treatment for concrete barriers and is also used for fixed objects up to 3 feet wide.
2. **Description:** The system consists of polyethylene cylinders with varying wall thickness, redirecting cables, a steel frame base, and a backup structure (see Exhibit 1620-2d).
3. **Function:** The redirecting cables are anchored in the concrete foundation at the front of the system and in the backup structure at the rear of the system. When hit head-on, the cylinders compress, absorb the impact energy, and immediately return to much of their original shape, position, and capabilities. For side impacts, the cables restrain the system enough to help prevent penetration and redirect the vehicle. It is anticipated that this system will need very few replacement parts or extensive repair.

4. **Foundation:** The system is installed on a concrete foundation.
5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is needed. "Excessive" is defined as steeper than 8% for the REACT 350.
6. **Manufacturer/Supplier:** Energy Absorption Systems

(h) **REACT 350 Wide**

1. **Purpose:** The REACT 350 Wide is a device that can be used to shield objects with widths up to 10 feet wide.
2. **Description:** The system consists of polyethylene cylinders with varying wall thickness, internal struts, space frame diaphragms, and a monorail (see Exhibit 1620-2d).
3. **Function:** When hit head-on, the cylinders compress, absorb the impact energy, and immediately return to much of their original shape, position, and capabilities. For side impacts, the system is designed to restrain and redirect the vehicle. It is anticipated that this system will need very few replacement parts or extensive repairs.
4. **Foundation:** The system is installed on a concrete foundation.
5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is needed. "Excessive" is defined as steeper than 8% for the REACT 350 Wide.
6. **Manufacturer/Supplier:** Energy Absorption Systems

(i) **Inertial Barrier**

Inertial barrier configurations are shown in the *Standard Plans*. If a situation is encountered where the configurations in the *Standard Plans* are not appropriate, contact the HQ Design Office for further information.

1. **Purpose:** Inertial barrier is an end treatment for concrete barrier and is used to mitigate fixed objects. This system does not provide redirection from a side impact.
2. **Description:** This system consists of an array of plastic containers filled with varying weights of sand (see Exhibit 1620-2d).
3. **Function:** The inertial barriers slow an impacting vehicle by the transfer of the momentum of the vehicle to the mass of the barrier. This system is not suitable where space is limited to less than the widths shown in the *Standard Plans*. Whenever possible, align inertial barriers so that an errant vehicle deviating from the roadway by 10° would be on a parallel path with the attenuator alignment (see the *Standard Plans*). In addition, inertial barriers do not provide any redirection and are not appropriate where high-angle impacts are likely.

4. **Foundation:** A concrete or paved surface is recommended.
 5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is needed. "Excessive" is defined as steeper than 5% for inertial barriers.
 6. **Manufacturer/Supplier:** Approved Inertial Barrier systems (sand barrel arrays) are listed in the Qualified Products List.
- (j) **SCI100GM / SCI70GM**
1. **Purpose:** The SCI100GM / SCI70GM are end treatments that can be used for concrete barrier and beam guardrail with widths up to 2 feet.
 2. **Description:** The system for both models consists of telescoping quadruple corrugated fender panels mounted on both sides of a series of tubular steel support frames (see Exhibit 1620-2e).
 3. **Function:** A hydraulic cylinder is compressed during a head-on impact. It is anticipated that this system will need very few replacement parts or extensive repairs.
 4. **Foundation:** The system is installed on a concrete or asphalt foundation. (See manufacturer's installation information for details.)
 5. **Slope:** 12H:1V or flatter slope between the edge of the traveled way and the near face of the unit.
 6. **Manufacturer/Supplier:** Work Area Protection Corp.

(2) **Work Zone (Temporary) Installation**

Several of the impact attenuators previously listed under the heading "Permanent Installations" are also appropriate for use in work zones or other temporary locations. The following is a list of these devices:

- QuadGuard
- QuadGuard Elite
- REACT 350
- REACT 350 Wide
- Inertial Barriers
- SCI100GM
- SCI70GM

The following systems are appropriate only in work zones or other temporary installations. However, the TRACC impact attenuator may be considered for permanent use, with the concurrence of WSDOT Maintenance personnel.

Descriptions of each work zone (or other temporary) system's purpose, parts, and functionality, as well as guidance for transition, foundation, and slope, are provided as follows and in Exhibit 1620-5:

(a) ABSORB 350

1. **Purpose:** The ABSORB 350 is an end treatment limited to temporary installations for both concrete barrier and the Quickchange Moveable Barrier (QMB).
2. **Description:** The system contains water-filled Energy Absorbing Elements. Each element is 2 feet wide, 2 feet 8 inches high, and 3 feet 3½ inches long (see Exhibits 1620-3a and 3b).
3. **Function:** The low-speed (below 45 mph) system uses five Energy Absorbing Elements, and the high-speed (45 mph and above) system uses eight. The energy of an impact is dissipated as the elements are crushed.
4. **Foundation:** The system does not need a paved foundation.
5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.
6. **Manufacturer/Supplier:** Barrier Systems, Inc.

(b) Advanced Dynamic Impact Extension Module 350 (ADIEM 350)

1. **Purpose:** The ADIEM 350 is limited to temporary installations where vehicle speeds are 45 mph or lower. It is generally used as an end treatment for concrete barrier. Currently, there are a few existing permanent units in service. It is permissible to reset these existing devices. However, some of these units may exhibit significant deterioration, and replacement may be the appropriate option.
2. **Description:** The system is 30 feet long and consists of ten lightweight concrete modules on an inclined base (see Exhibit 1620-3a).
3. **Function:** An inclined base provides a track for placement of the modules and provides redirection for side impacts for roughly half the length. The energy of an impact is dissipated as the concrete modules are crushed.
4. **Foundation:** The system does not need a paved foundation.
5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is needed. Excessive is defined as steeper than 8% for the ADIEM 350.
6. **Manufacturer/Supplier:** Trinity Industries, Inc.

(c) QuadGuard CZ

This system is like the permanent QuadGuard listed for permanent systems above, except that it can be installed on a 6-inch-minimum-depth asphalt concrete surface that has a 6-inch-minimum-depth compacted base (see Exhibit 1620-3a).

(d) Reusable Energy Absorbing Crash Terminal (REACT 350)

This is the same system listed for permanent systems above except that it can be installed on a 6-inch-minimum-depth asphalt concrete surface that has a 6-inch-minimum-depth compacted base (see Exhibit 1620-2d).

(e) Non-Redirecting Energy Absorbing Terminal (N-E-A-T)

1. **Purpose:** The N-E-A-T system is an end treatment for temporary concrete barrier where vehicle speeds are 45 mph or lower.
2. **Description:** The N-E-A-T system's cartridge weighs about 300 pounds and is 9 feet 8 inches long. The system consists of aluminum cells encased in an aluminum shell with steel backup, attachment hardware, and transition panels. It can be attached to the ends of New Jersey shaped portable concrete barrier and the Quickchange Moveable Barrier (see Exhibit 1620-3b).
3. **Function:** The energy of an impact is dissipated as the aluminum cells are crushed.
4. **Foundation:** The system does not need a paved foundation.
5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.
6. **Manufacturer/Supplier:** Energy Absorption Systems

(f) Trinity Attenuating Crash Cushion (TRACC)

1. **Purpose:** The TRACC is an end treatment for concrete barriers. It is limited to use in construction or other work zones on a temporary basis.
2. **Description:** The 21-foot-long TRACC includes four major components: a pair of guidance tracks, an impact sled, intermediate steel frames, and 10-gauge W-beam fender panels (see Exhibit 1620-3b).
3. **Function:** The sled (impact face) is positioned over the upstream end of the guidance tracks and contains a hardened steel blade that cuts the metal plates on the sides of the guidance tracks as it is forced backward when hit head-on.
4. **Foundation:** The system needs a concrete foundation.
5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.
6. **Manufacturer/Supplier:** Trinity Industries, Inc.

(g) Inertial Barrier

This is the same system listed for permanent systems above. It is not suitable where space is limited to less than the widths shown in the *Standard Plans* (see Exhibit 1620-2d).

(h) Truck-Mounted Attenuator (TMA)

TMAs are portable systems mounted on trucks. They are intended for use in work zones and for temporary applications.

(i) Triton CET

1. **Purpose:** The Triton CET is an end treatment limited to temporary concrete barrier installations.

2. **Description:** The system contains water-filled Energy Absorbing Elements (see Exhibit 1620-3b).
3. **Function:** The system uses six Energy Absorbing Elements. The energy of an impact is dissipated as the elements are crushed.
4. **Foundation:** The system does not need a paved foundation.
5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.
6. **Manufacturer/Supplier:** Energy Absorption, Inc.

(j) **QUEST**

1. **Purpose:** The QUEST is an end treatment limited to temporary applications. This system is designed to shield features 2 feet or less in width.
2. **Description:** The system consists of two front anchor assemblies; a nose assembly containing an integrated trigger assembly; two shaper rail assemblies; a support rail assembly with two energy-absorbing tube shapers; a diaphragm assembly; a bridge assembly; two rear rails; a freestanding backup assembly; and W-beam fender panels (see Exhibit 1620-3b). Transition panels are needed when traffic approaches from the rear of the unit.
3. **Function:** During head-on impacts, the Quest system telescopes rearward and energy is absorbed through momentum transfer, friction, and deformation. When impacted from the side, the QUEST system restrains lateral movement by dynamic tension developed between the end restraints.
4. **Foundation:** The system is installed on a concrete or asphalt foundation. (See manufacturer's installation information for details.) The unit is attached to the road surface with 30 to 34 anchors.
5. **Slope:** 12H:1V (8%) or flatter slope between the edge of the traveled way and the near face of the unit is needed. In addition, if the slope varies (twists) more than 2% over the length of the system, a concrete leveling pad may be needed.
6. **Manufacturer/Supplier:** Energy Absorption Systems, Inc.

(3) Older Systems

The following systems are in use on Washington State highways and may be left in place or reset. New installations of these systems need approval from the HQ Design Office.

(a) **Sentre**

The Sentre is a guardrail end treatment. Its overall length of 17 feet allowed it to be used where space was not available for a guardrail transition and terminal. The system is very similar to the QuadTrend 350 in both appearance and function except that it uses thrie beam fender panels instead of the quadruple corrugated panels. This system needs a transition when used to terminate rigid barriers (see Exhibit 1620-4a).

(b) TREND

The TREND is an end treatment with a built-in transition and was used at the end of rigid barriers including bridge rails. The system is similar to the QuadTrend 350 except that it uses thrie beam fender panels (see Exhibit 1620-4a).

(c) Guard Rail Energy Absorption Terminal (G-R-E-A-T)

This system was primarily used as an end treatment for concrete barrier. It is similar to the QuadGuard except that it uses thrie beam fender panels (see Exhibit 1620-4a).

(d) Low-Maintenance Attenuator System (LMA)

The LMA is an end treatment for concrete barrier and beam guardrail and was used for fixed objects up to 3 feet wide. The system is similar to the QuadGuard Elite except that it uses thrie beam fender panels and rubber cylinders (see Exhibit 1620-4b).

(e) Hex-Foam Sandwich

The Hex-Foam Sandwich system (see Exhibit 1620-4b) is an end treatment for beam guardrail and concrete barrier and was also used for fixed objects 3 feet or more in width. This system consists of a number of Hex-Foam cartridges containing an energy absorption material separated by a series of diaphragms and restrained by anchor cables. It is installed on a concrete slab. Impact energy is absorbed by the internal shearing of the cartridges and crushing of the energy absorption material. The lapped panels on the perimeter serve to redirect vehicles for side impacts. If the site has grade or cross slope in excess of 5%, additional site preparation or modification to the units in accordance with the manufacturer's literature is needed.

1620.02 Design Criteria

The following design criteria apply to new or reset permanent and temporary impact attenuators. The design criteria also apply to existing systems to be left in place when the Barrier Terminals and Transition Sections columns on a design matrix apply to the project (see Chapter 1100).

Impact attenuators are placed so that they do not present a feature that needs mitigating in relation to opposing traffic. For median and reversible lane locations, the backup structure or attenuator-to-object connection is designed to help in aiding opposing traffic from being snagged. It is desirable that existing curbing be removed and the surface smoothed with asphalt or cement concrete pavement before an impact attenuator is installed. However, curbs 4 inches or less in height may be retained depending on the feasibility of their removal.

In general, attenuators are aligned parallel to the roadway except the inertial barriers.

1620.03 Selection

When selecting an impact attenuator system, consider the:

- Posted speed.
- Average Daily Traffic (ADT).
- Repair crew exposure.
- Proximity to the roadway.
- Anticipated number of yearly impacts.

- Available space (length and width).
- Maintenance costs.
- Initial cost.
- Duration (permanent or temporary use).
- Portion of the impact attenuator that is redirective/nonredirective (see Exhibits 1620-5 and 1620-6).

It is very important for designers to consider the portion of an impact attenuator that is designed to redirect vehicles during a side impact of the unit. It is crucial to consider that fixed objects, either permanent or temporary (such as construction equipment), not be located behind the nonredirective portion of these devices.

The posted speed is a consideration in the selection of the QuadGuard, REACT 350, Universal TAU-II, and Inertial Barrier systems. Use Exhibit 1620-1 to select the permanent system sizes needed for the various posted speeds.

| Posted Speed (mph) | Quad Guard (Bays) | Universal TAU-II* (Bays) | REACT 350 (Cylinders) | Inertial Barrier (Type) |
|--------------------|-------------------|--------------------------|-----------------------|-------------------------|
| 40 or less | 3 | 2-3 | 4 | 1 |
| 45 | 4 | 3-4 | 6 | 2 |
| 50 | 5 | 4-5 | 6 | 3 |
| 55 | 6 | 5-7 | 6 | 4 |
| 60 | 6 | 7-8 | 9 | 5 |
| 65 | 8 | 7-8 | 9 | 6 |
| 70 | 9 | 7-8 | 9 | 6 |

*Dependent on the width of the system.

Impact Attenuator Sizes

Exhibit 1620-1

If it is anticipated that a large volume of traffic will be traveling at speeds higher than the posted speed limit, then the next larger unit may be specified.

For a comparison summary of space and initial cost information related to the impact attenuator systems, see Exhibit 1620-5.

When maintenance costs are considered, anticipate the average annual impact rate. If few impacts are anticipated, lower-cost devices such as inertial barriers might meet the need. Inertial barriers have the lowest initial cost and initial site preparation. However, maintenance will be costly and necessary after each impact. Labor and equipment are needed to clean up the debris and install new containers (barrels). Also, inertial barriers are not be used where flying debris might be a danger to pedestrians.

In selecting a system, one consideration is the anticipated exposure to traffic that the workers making the repairs may encounter. In areas with high traffic exposure, a low-maintenance system that can be repaired quickly is most desirable. Some systems need nearly total replacement or replacement of critical components (such as cartridges or braking mechanisms) after a head-on impact, while others simply need resetting. Consult with the Area Maintenance Superintendant who will be maintaining the systems.

(1) Low-Maintenance Category

The REACT 350, SCI100GM / SCI70GM, and the QuadGuard Elite have a higher initial cost, requiring substantial site preparation, including a backup or anchor wall in some cases and cable anchorage at the front of the installation. However, repair costs are comparatively low, with labor being the main expense. Maintenance might not be needed after minor side impacts with these systems.

Limit the selection of impact attenuators to low-maintenance devices for:

- Locations with an average daily traffic (ADT) of 25,000 or more or a history/anticipation of multiple impacts each year.
- Sites with limitations on repair time or locations within 10 feet of the traveled way.
- Sites requiring night repairs or gore locations.

The QuadGuard Elite, SCI100GM, and REACT 350 are considered low-maintenance devices. Consider upgrading existing ADIEM, G-R-E-A-T, and Hex-Foam impact attenuators to these low-maintenance devices when the repair history shows one or more impacts per year over a three- to five-year period.

To be included in the low-maintenance category, a threshold on repair parts for each impact will be \$500 or less per impact. A threshold on repair time considering a four-person crew will be one hour or less.

Approved attenuator systems that have little or no performance history in Washington State may be considered low-maintenance devices with concurrence from the HQ Design Office and the Area Maintenance Superintendent (or designee) responsible for maintaining the device. Product vendors or distributors are responsible for obtaining the concurrence from HQ Design Office representatives.

To be included in the low-maintenance category, a threshold on repair parts for each impact will be \$500 or less per impact. A threshold on repair time considering a four-person crew will be one hour or less. Attenuators selected as low-maintenance devices will:

- Be approved for use in Washington State (see 1620.01).
- Have been in use for a minimum of two years.
- Include a two-year “In-Service Evaluation Report” based on the usage in Washington and/or other states that represents at least 25 impacts as a basis for the repair history. The impacts provided will include both side and leading end impacts. The minimum information in the “In-Service Evaluation Report” will include:
 - Number of impacts and type (such as side or front).
 - Impacting vehicle type with a description of collision (such as speeds or impact angle).
 - Specific location of impacts.
 - Repair dates.
 - Parts needed for repair (itemized list).
 - Cost of parts.
 - Repair time (total hours).
 - Repair personnel contact information.

It is very important to consider that each application is unique when selecting impact attenuators for use in particular applications. This applies to both permanent and temporary installations. When specifying the system or systems that can be used at a specific location, the list shown in Exhibit 1620-5 is to be used as a starting point. As the considerations discussed previously are analyzed, inappropriate systems may be identified and eliminated from further consideration. Systems that are not eliminated may be appropriate for the project. When the site conditions vary, it might be necessary to have more than one list of acceptable systems within a contract. Systems are not to be eliminated without documented reasons. Also, wording such as "or equivalent" is not to be used when specifying these systems. If only one system is found to be appropriate, then approval from the Assistant State Design Engineer of a public interest finding for the use of a sole source proprietary item is needed.

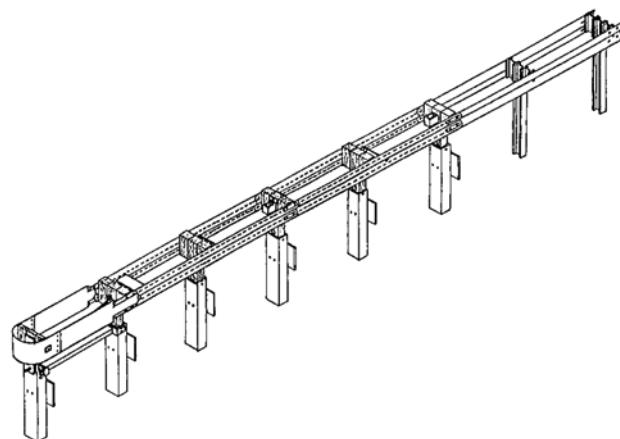
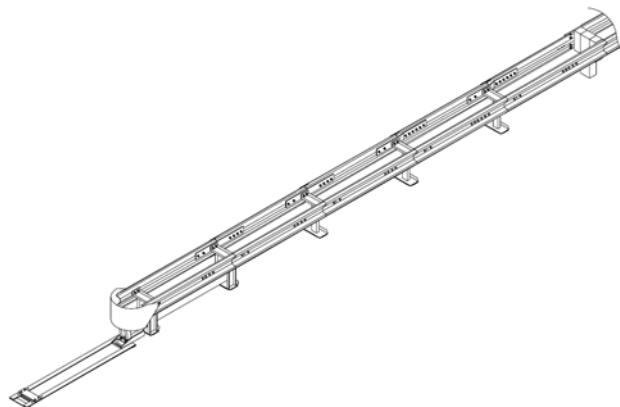
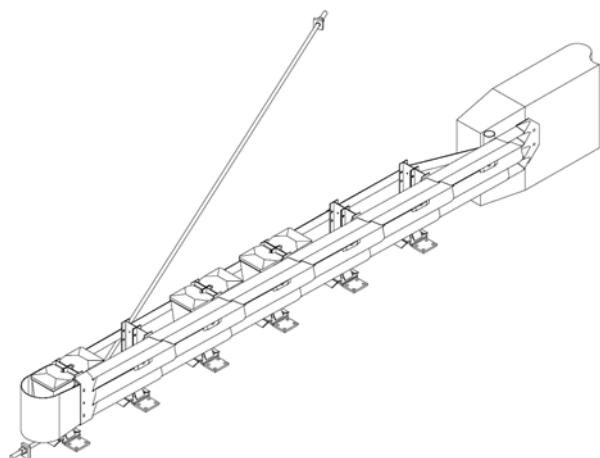
When a transition to connect with a concrete barrier (see Exhibit 1620-5) is needed, the transition type and connection are to be specified and are included in the cost of the impact attenuator. (See Chapter 1610 for information on the transitions and connections to use.)

Contractors can be given more flexibility in the selection of work zone (temporary) systems, since long-term maintenance and repair are not a consideration.

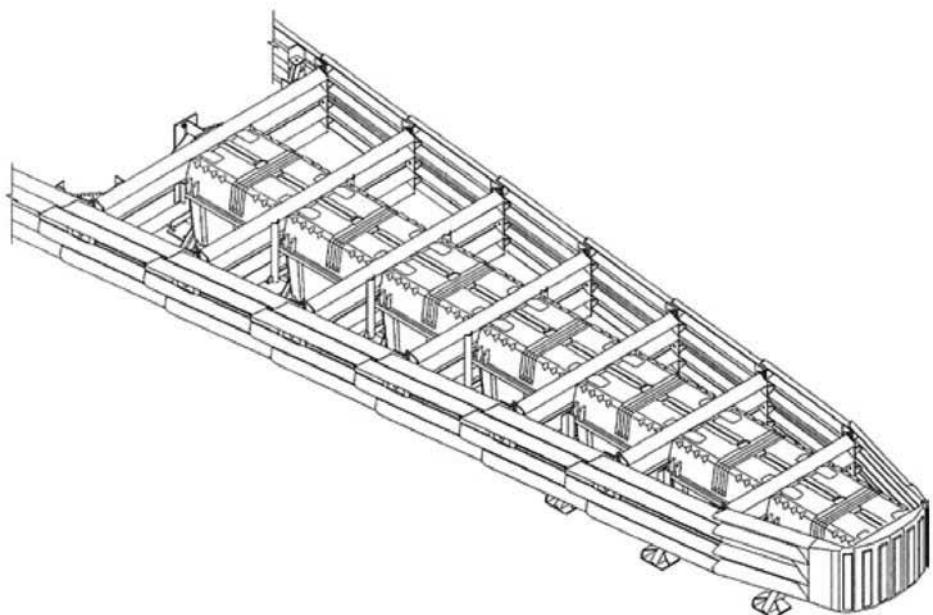
1620.04 Documentation

For the list of documents required to be preserved in the Design Documentation Package and the Project File, see the Design Documentation Checklist:

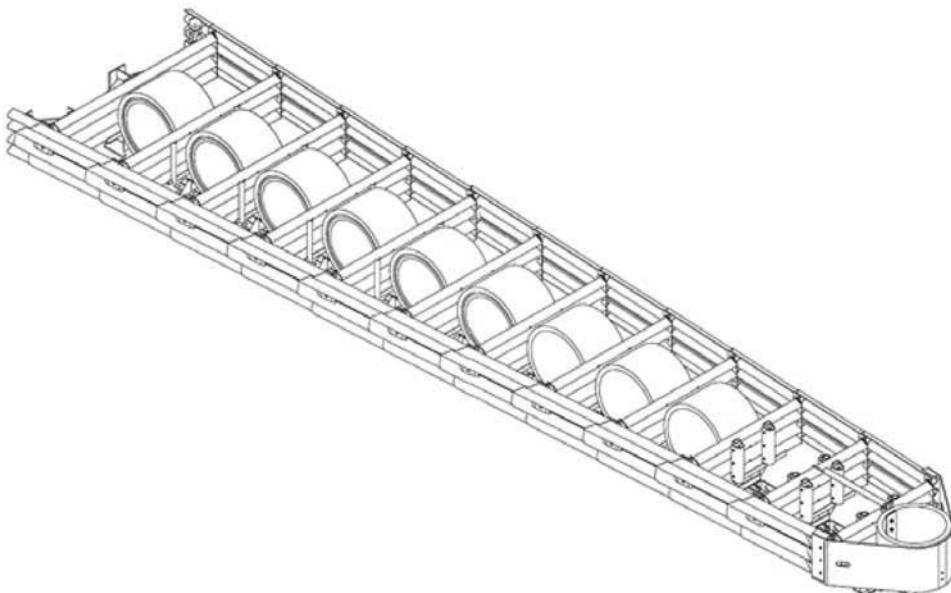
☞ www.wsdot.wa.gov/design/projectdev/

**CAT - 350****Brakemaster****QuadTrend 350**

Impact Attenuator Systems: Permanent Installations *Exhibit 1620-2a*

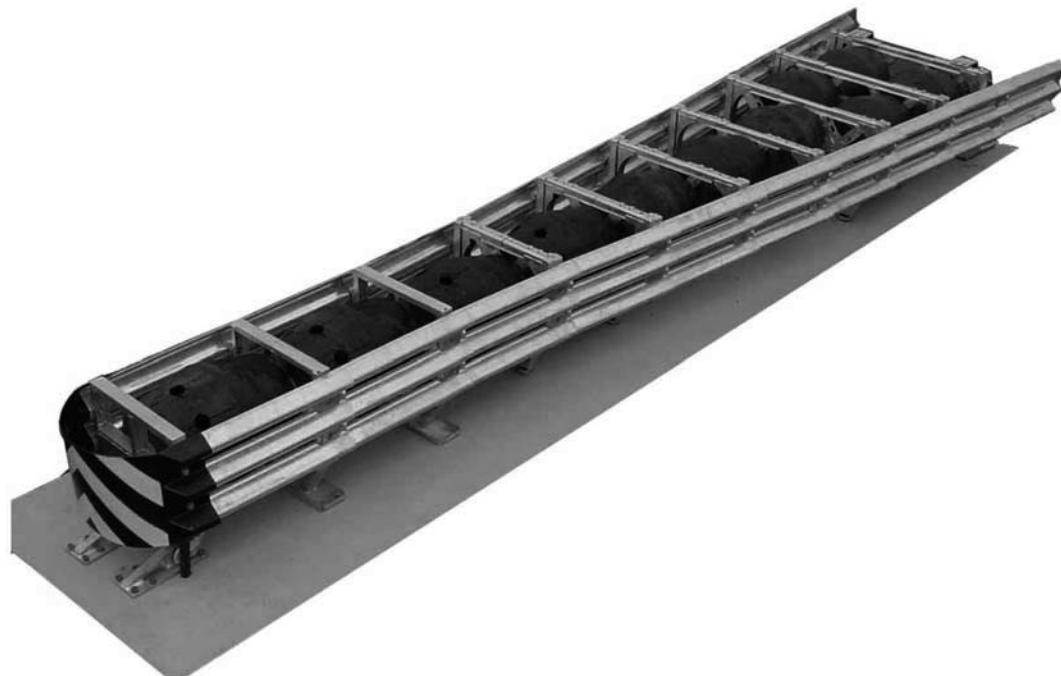


QuadGuard



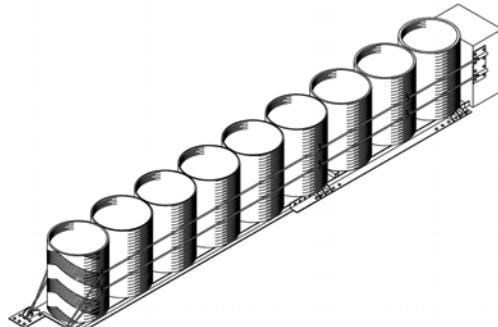
QuadGuard Elite

Impact Attenuator Systems: Permanent Installations
Exhibit 1620-2b

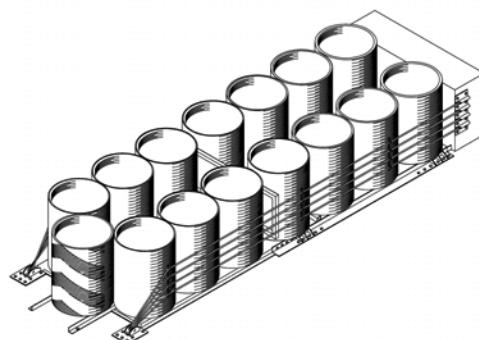


Universal TAU - II

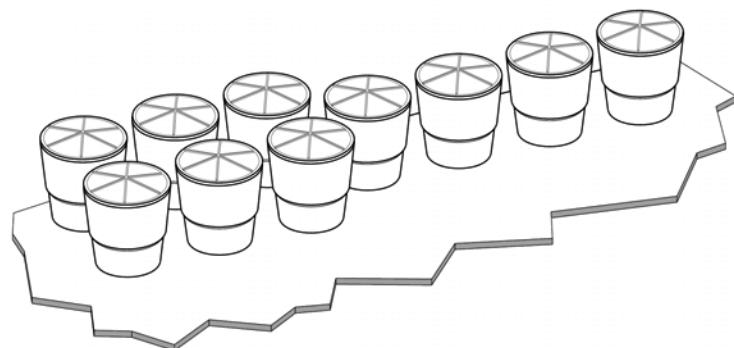
Impact Attenuator Systems: Permanent Installations
Exhibit 1620-2c



REACT 350



REACT 350 WIDE



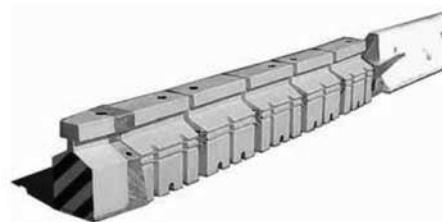
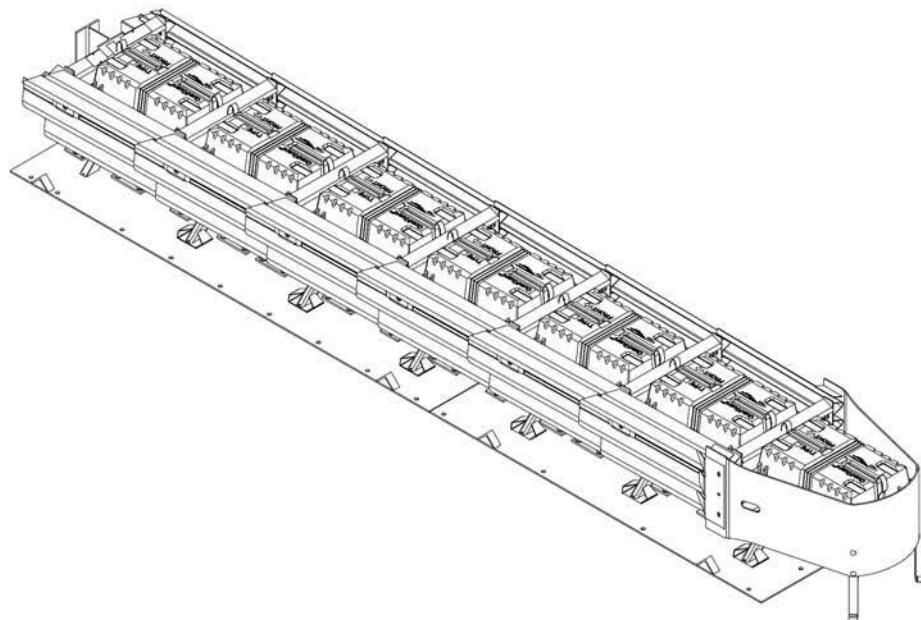
INERTIAL BARRIER

Impact Attenuator Systems: Permanent Installations
Exhibit 1620-2d



SCI100GM / SCI70GM

Impact Attenuator Systems: Permanent Installations
Exhibit 1620-2e

**ABSORB 350****ADIEM 350****QuadGuard CZ**

Impact Attenuator Systems: Work Zone Installations *Exhibit 1620-3a*



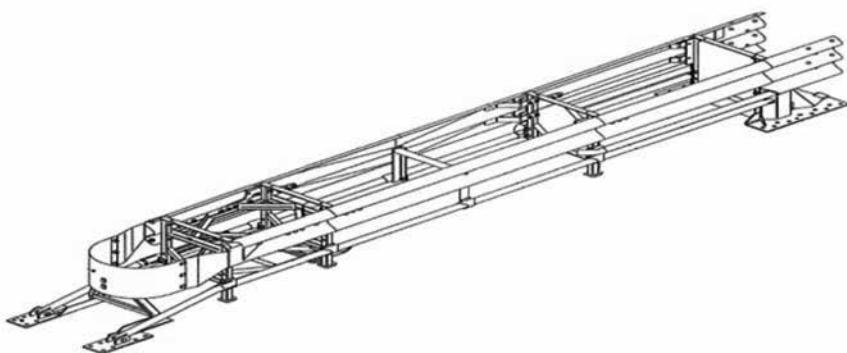
N-E-A-T



TRACC



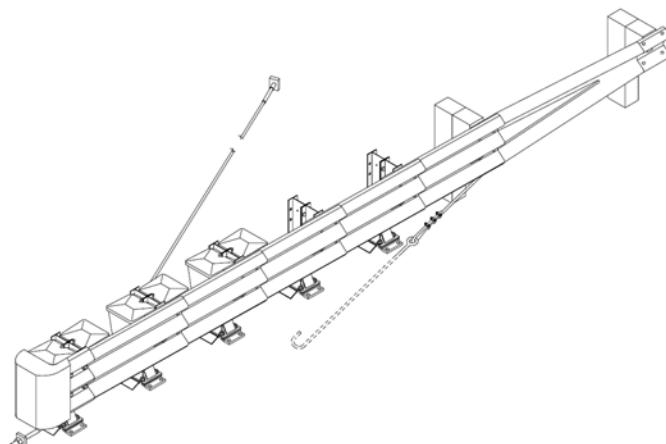
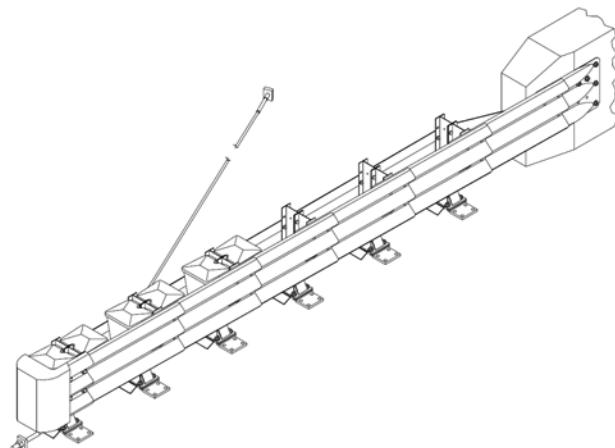
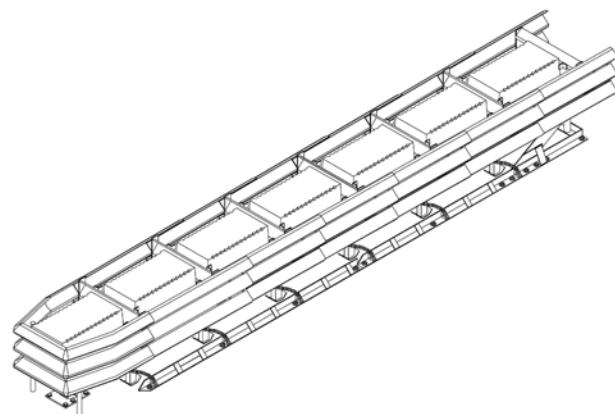
Triton CET

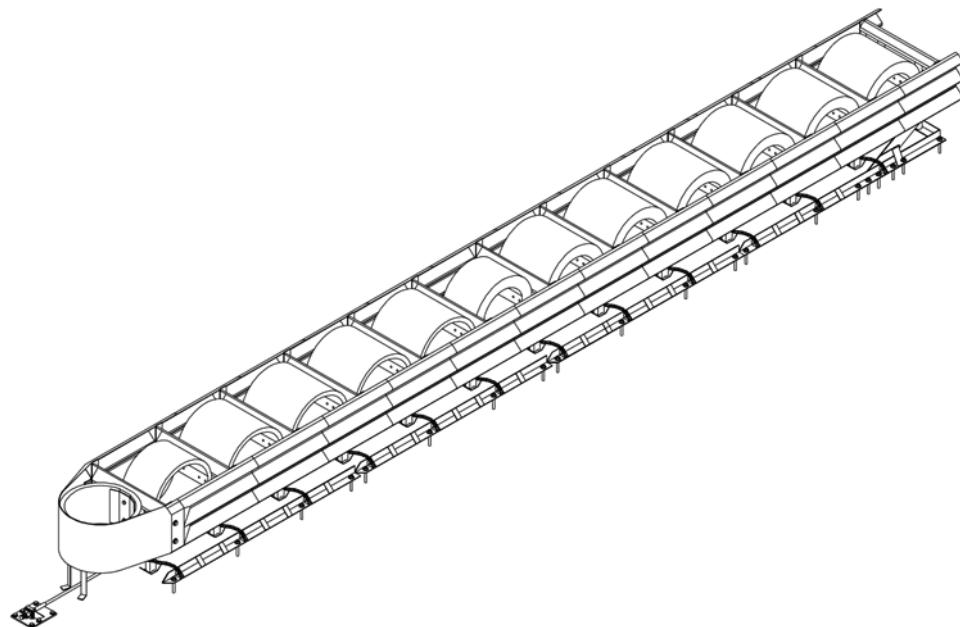
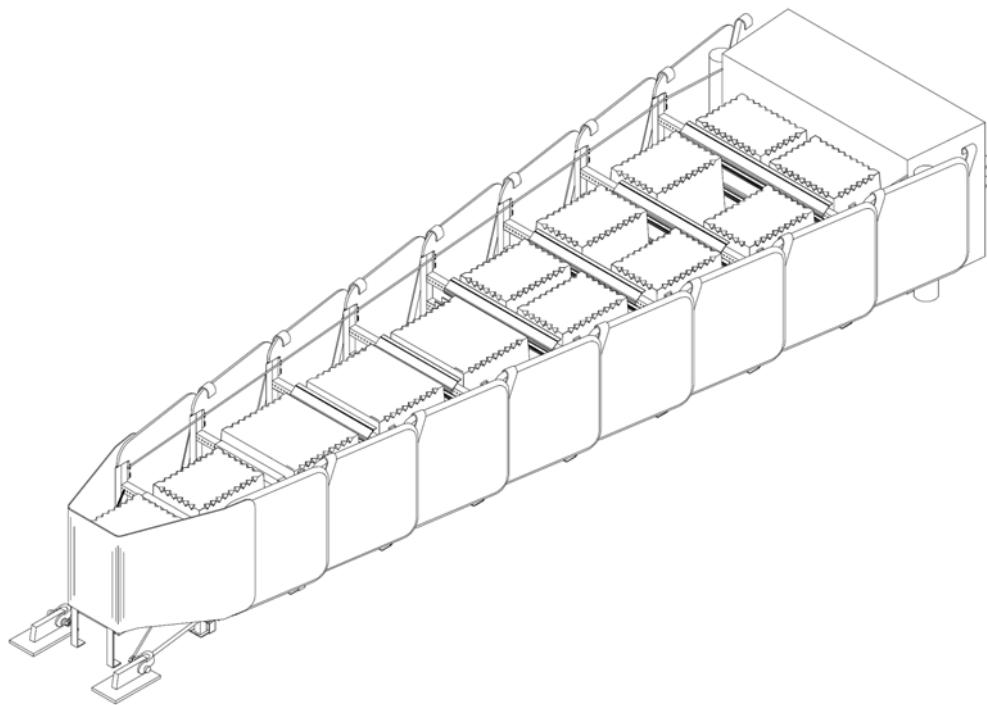


QUEST

Impact Attenuator Systems: Work Zone Installations

Exhibit 1620-3b

**Sentre****TREND****G-R-E-A-T****Impact Attenuator Systems: Older Systems**
Exhibit 1620-4a

**LMA****Hex-Foam Sandwich**

Impact Attenuator Systems: Older Systems
Exhibit 1620-4b

Impact Attenuator Systems (All dimensions in feet)

| System | (P) Permanent (T) Temporary (B) Both | Approximate Outside Width ^[10] | Approximate System Length ^[11] | Transition to Rigid System Needed? | Distance Beyond Length of Need (See Exhibit 1620-6) | Initial Cost Category ^[1] |
|--------------------------------|--|---|---|------------------------------------|---|--------------------------------------|
| CAT 350 ^[2] | P | 2.5 | 31.3 | Y | 18.8 | A |
| Brakemaster 350 ^[2] | P | 2.1 | 31.5 | Y | 15.8 | A |
| QuadTrend – 350 ^[6] | P | 1.3 | 20.0 | N | 10.5 | A |
| Universal TAU-II | P | 2.9–8.7 | 12.0–26.0 ^[4] | N | 3.0 | B ^[5] |
| QuadGuard | B | 2.8–10.8 | 13.1–32.5 ^[4] | N | 3.3 | B ^[5] |
| QuadGuard Elite | B | 2.8–8.3 | 23.8–35.5 | N | 3.3 | D |
| REACT 350 | B | 4 | 13.8–30.2 ^[4] | N | 4.3 | C ^[5] |
| REACT 350 Wide | B | 5.7–10.7 | 30.8–34.8 | Y | 4.3 | D ^[5] |
| Inertial Barriers | B | 7 | 17.0–34.5 ^[4] | N | [3] | A ^[5] |
| SCI100GM | B | 3.1 | 21.5 | Y | 3 | C |
| SCI70GM ^[8] | B | 2.8 | 13.5 | Y | 3 | B |
| ABSORB 350 ^[9] | T | 2 | 19.0–32.0 | Y | [3] | A ^[5] |
| ADIEM 350 ^{[7][8]} | T | 2.7 | 30 | N | 14.1 | B |
| QuadGuard CZ | T | 2.75–3.25 | 13.1–22.1 | N | 3.3 | C ^[5] |
| N-E-A-T ^[8] | T | 1.9 | 9.7 | N | [3] | A ^[5] |
| TRACC ^[12] | T | 2.6 | 21.3 | N | 8 | B |
| Triton CET ^[9] | T | 1.8 | 40 | N | [3] | A |
| QUEST | T | 2.8 | 22.2 | Y | 3.5 | B |

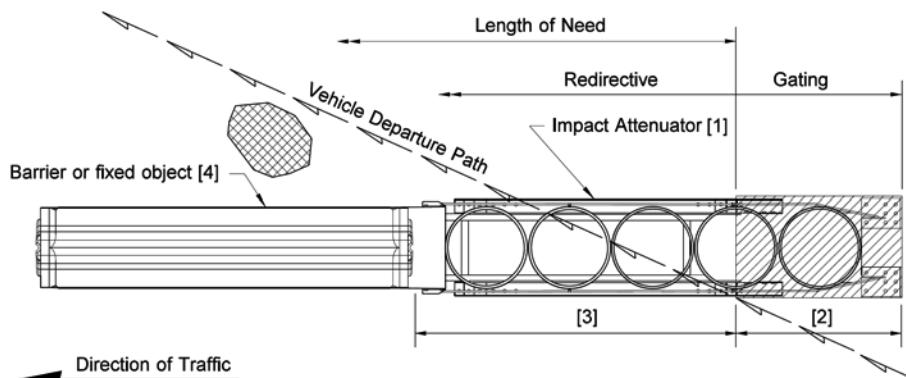
For table notes, see the following page.

Impact Attenuator System Comparison
Exhibit 1620-5

Notes:

- [1] A (\$5,000 to \$10,000); B (\$10,000 to \$15,000); C (\$15,000 to \$25,000); D (\$25,000 to \$50,000). These are rough initial cost estimates; verify actual costs through manufacturers/suppliers. Some products are priced very close to the margin between cost categories.
- [2] Generally for use with double-sided beam guardrail. Usage as an end treatment for concrete barrier needs a transition.
- [3] The N-E-A-T, Inertial Barriers, Triton CET, and ABSORB 350 may only be used beyond the length of need.
- [4] For sizes or configuration type, see Exhibit 1620-1.
- [5] The lengths of the Universal TAU-II, QuadGuard, QuadGuard Elite, REACT 350, REACT 350 Wide, ABSORB 350, QuadGuard CZ, and Inertial Barriers vary because their designs are dependent upon speed. Costs indicated are for a typical 60 mph design. In addition to length, several of the systems also vary in width. For estimating purposes, the following model widths were considered.
 - Universal TAU II – 24"
 - QuadGuard – 24"
 - QuadGuard Elite – 24"
 - REACT 350 Wide – 60"
 - QuadGuard CZ – 24"
- [6] Generally for use at the ends of bridges where installation of a beam guardrail transition and terminal is not feasible.
- [7] Generally for use with concrete barrier. Other uses may need a special transition design.
- [8] Use limited to highways with posted speeds of 45 mph or lower.
- [9] Test Level 3 version on high-speed facilities should be limited to locations where the likelihood of being hit is low.
- [10] The given dimension is the approximate outside width of each system. In most cases, this width is slightly wider than the effective width. To determine the width of an object that may be shielded, refer to the manufacturer's specifications. (See the WSDOT Design Policy, Standards, & Safety Research Unit's website for links to this information.)
- [11] The given dimension is the approximate system length. The effective length may vary depending on such factors as the physical design and type of anchorage used. To determine the total length needed, refer to the manufacturer's specifications. (See the WSDOT Design Policy, Standards, & Safety Research Unit's website for links to this information.)
- [12] May be considered for permanent installations with concurrence of Maintenance personnel.

Impact Attenuator System Comparison
Exhibit 1620-5 (continued)

**Notes:**

- [1] Impact attenuator type and manufacturer varies with application (see Exhibit 1620-5).
- [2] Distance beyond the length of need (see Exhibit 1620-5). This portion is nonredirective (gating).
- [3] This portion is redirective and can be included as part of the barrier needed to satisfy length of need.
- [4] Concrete barrier shown for illustration purposes only. Type of object varies.

Impact Attenuator Distance Beyond Length of Need
Exhibit 1620-6