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USACE / NAVFAC / AFCEA / NASA UFGS-34 71 13.19 (April 2006)  
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Preparing Activity: USACE Replacing without change  
UFGS-02840 (August 2003)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 9 October 2006

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### SECTION TABLE OF CONTENTS

#### DIVISION 34 - TRANSPORTATION

##### SECTION 34 71 13.19

##### ACTIVE VEHICLE BARRIERS

04/06

#### PART 1 GENERAL

- 1.1 REFERENCES
- 1.2 SUBMITTALS
- 1.3 GENERAL REQUIREMENTS
- 1.4 NAMEPLATES
- 1.5 DELIVERY AND STORAGE
- 1.6 SPARE PARTS
- 1.7 MANUFACTURER'S SERVICES

#### PART 2 PRODUCTS

- 2.1 RETRACTABLE BARRIERS
  - 2.1.1 Powered Retractable Barrier
    - 2.1.1.1 Failure Modes of Operation
    - 2.1.1.2 Electric Motors
    - 2.1.1.3 System
    - 2.1.1.4 Hydraulic Power Unit
    - 2.1.1.5 Hydraulic Power Unit Enclosure
  - 2.1.2 Manual Retractable Barriers
- 2.2 RETRACTABLE BOLLARDS
  - 2.2.1 Powered Retractable Bollards
    - 2.2.1.1 Failure Modes of Operation
    - 2.2.1.2 Electric Motors
    - 2.2.1.3 System
    - 2.2.1.4 Hydraulic Power Unit
    - 2.2.1.5 Hydraulic Power Unit Enclosure
  - 2.2.2 Manual Retractable Bollards
- 2.3 CRASH GATE
  - 2.3.1 Powered Crash Gate
    - 2.3.1.1 Failure Mode of Operation
    - 2.3.1.2 Hydraulic Power Unit
    - 2.3.1.3 Hydraulic Power Unit Enclosure
  - 2.3.2 Manual Crash Gate
- 2.4 CRASH BEAM
  - 2.4.1 Powered Crash Beam

2.4.1.1	Failure Mode of Operation
2.4.1.2	Hydraulic Power Unit
2.4.1.3	Hydraulic Power Unit Enclosure
2.4.2	Manual Crash Beam
2.5	PORTABLE RETRACTABLE BARRIER
2.5.1	Powered Portable Retractable Barrier
2.5.1.1	Failure Modes of Operation
2.5.1.2	Electric Motors
2.5.1.3	System
2.5.1.4	Hydraulic Power Unit
2.5.2	Manual Retractable Portable Barriers
2.6	PORTABLE CRASH BEAM
2.6.1	Powered Portable Crash Beam
2.6.1.1	Failure Mode of Operation
2.6.1.2	Hydraulic Power Unit
2.6.1.3	Hydraulic Power Unit Enclosure
2.6.2	Manual Portable Crash Beam
2.7	ELECTRICAL WORK
2.8	CONTROL PANEL
2.8.1	Voltage
2.8.2	Main Control Panel
2.8.3	Remote Control Panel
2.9	MISCELLANEOUS EQUIPMENT
2.9.1	Safety Equipment
2.9.1.1	Barrier Systems Sensors
2.9.1.2	Traffic Lights
2.9.2	Warning Annunciator
2.9.3	Heater
2.9.4	Signage
2.9.5	Vertical Arm Gates (Traffic Arms)
2.9.6	Vehicle Barrier Vertical Arm Gate (Traffic Arm)
2.10	FINISH
2.11	CONCRETE
2.12	WELDING
2.13	PAVEMENT
PART 3	EXECUTION
3.1	INSTALLATION
3.2	HYDRAULIC LINES
3.3	PIT DRAINAGE
3.4	ELECTRICAL
3.5	FIELD TESTING
3.6	FIELD TRAINING

-- End of Section Table of Contents --

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### SECTION 34 71 13.19

#### ACTIVE VEHICLE BARRIERS 04/06

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NOTE: This guide specification covers the requirements for portable, semi-permanent, permanent, power-assisted or manually deployed active vehicle barriers.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

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## PART 1 GENERAL

### 1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS  
(AASHTO)

AASHTO HB-17 (2002; Errata 2003) Standard  
Specifications for Highway Bridges

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M (2006) Structural Welding Code - Steel

ASTM INTERNATIONAL (ASTM)

ASTM A 106/A 106M (2004b) Seamless Carbon Steel Pipe for  
High-Temperature Service

ASTM D 3034 (2004a) Type PSM Poly(Vinyl Chloride)  
(PVC) Sewer Pipe and Fittings

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250 (2003) Enclosures for Electrical Equipment  
(1000 Volts Maximum)

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE J517 (2003) Hydraulic Hose

U.S. FEDERAL HIGHWAY ADMINISTRATION (FHWA)

FHWA SA-89-006 (1988) Manual on Uniform Traffic Control  
Devices for Streets and Highways

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910 Occupational Safety and Health Standards

UNDERWRITERS LABORATORIES (UL)

UL 486A-486B (2003; Rev thru Apr 2004) Wire Connectors

## 1.2 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

#### SD-02 Shop Drawings

Installation[; G][; G, [\_\_\_\_]]  
Equipment[; G][; G, [\_\_\_\_]]  
Electrical Work[; G][; G, [\_\_\_\_]]

Detail drawings containing complete wiring and schematic diagrams, and any other details required to demonstrate that the system has been coordinated and will properly function as a unit. Drawings shall show proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work including foundation and clearances for maintenance and operation. Detail drawings shall include a copy of the Department of State certificate of barrier performance.

#### SD-03 Product Data

##### Vehicle Barriers

A complete list of equipment, materials, including industrial standards used and how they apply to the applicable component and manufacturer's descriptive data and technical literature, catalog cuts, and installation instructions. Information necessary to document a minimum 1-year successful field operation performance history for each type of vehicle barrier installed.

## Spare Parts

Spare parts data for each different item of material and equipment used, after approval of the detail drawings. The data shall include a complete list of parts and supplies, with current unit prices and source of supply.

## SD-06 Test Reports

### Field Testing

Test reports in booklet form showing all field tests, including component adjustments and demonstration of compliance with the specified performance criteria, upon completion and testing of the installed system. Each test report shall indicate the final position of controls.

## SD-10 Operation and Maintenance Data

### Vehicle Barriers[; G][; G, [\_\_\_\_]] Operating and Maintenance Instructions

Data Package 4 in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

[Six] [\_\_\_\_] copies of operation and maintenance manuals, a minimum of 2 weeks prior to field training. One complete set prior to performance testing and the remainder upon acceptance. Manuals shall be approved prior to acceptance. Operation manuals shall outline the step-by-step procedures required for system startup, operation, and shutdown. The manuals shall include the manufacturer's name, model number, service manual, parts list, and brief description of all equipment and their basic operating features. Maintenance manuals shall include routine maintenance procedures, possible breakdowns and repairs, and troubleshooting guide. The manuals shall include piping layout, equipment layout, and simplified wiring and control diagrams of the system as installed. The manuals shall also include synthetic biodegradable hydraulic oil types to be used for ambient temperature ranges of minus 34 degrees C minus 30 degrees F to plus 66 degrees C 150 degrees F to cover winter operation, summer operation, and ambient temperature ranges in between.

## 1.3 GENERAL REQUIREMENTS

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**NOTE: Performance levels are based on the following:**

**1. The Department of State (DOS) publication  
SD-SDT-02.01 Specification for Vehicle Crash Testing  
of Perimeter Barriers and Gates (April 1985) in  
which:**

Impact Conditions are:

Condition Designation	Vehicle Weight	Impact Speed	Kinetic Energy
K4	6,800 kg (15,000 lb)	48 km/h (30 mph)	610 kJ (450,000 ft-lb)
K8	6,800 kg (15,000 lb)	65 km/h (40 mph)	1084 kJ (800,000 ft-lb)
K12	6,800 kg (15,000 lb)	80 km/h (50 mph)	1695 kJ (1,250,000 ft-lb)

Performance Levels are:

(a) L 3.0 Vehicle and cargo are to be stopped although vehicle partial penetration and/or barrier deflection of up to 1 m (3 feet) permitted.

(b) L 2.0 Vehicle and cargo are to be stopped although vehicle partial penetration and/or barrier deflection of up to 6 m (20 feet) is permitted.

(c) L 1.0 Vehicle is disabled and does not travel more than 15 m (50 feet) after impact.

2. Prior to 2001, the Department of the Navy had its own test standard for Vehicle-Crash-Resistant Barrier Requirements. Since then, the Navy has discontinued referencing its standard and now references the DOS specification for certified vehicle barriers. This guide specification still recognizes barriers originally certified under the Navy standard. These barriers are identified as such in their respective paragraph of PART 2 PRODUCTS. The Department of the Navy publication Operational Requirement No. 098-09-88: Operational Requirements for Secure Structures Ashore (Locks and Barriers, 1986) in which:

Vehicle-Crash-Resistant Barrier Requirements are:

Security Level	Vehicle Weight	Impact Speed	Kinetic Energy
HIGH	4,535 kg (10,000 lb)	80 km/h (50 mph)	1133 kJ (836,000 ft-lb)
LOW	4,535 kg (10,000 lb)	24 km/h (15 mph)	102 kJ (75,000 ft-lb)

Performance Levels are:

(a) For the high security level, vehicle penetration from 0 to 3 m (0 to 10 feet) is permitted.

(b) For the low security level, vehicle penetration from 15 to 30 m (50 to 100 feet) is permitted.

3. Because kinetic energy is a function of the square of the velocity, the vehicle's speed has more significance than its weight. Therefore, limiting a vehicle's speed reduces the kinetic energy the barrier must resist resulting in a lower barrier cost. Vehicle barrier requirements are within the chart combinations below:

#### VEHICLE BARRIER TESTED COMBINATIONS

VEHICLE WEIGHT (kg)	VEHICLE SPEED (kph)	VEHICLE PENETRATION (m)
6,000	48	0.91
6,000	48	6
6,000	48	15
6,000	65	0.91
6,000	65	6
6,000	65	15
6,000	80	0.91
6,000	80	6
6,000	80	15
4,536	80	0 to 3
4,536	24	15 to 30

#### VEHICLE BARRIER TESTED COMBINATIONS

VEHICLE WEIGHT (lb.)	VEHICLE SPEED (mph)	VEHICLE PENETRATION (ft.)
15,000	30	<= 3
15,000	30	<=20
15,000	30	<=50
15,000	40	<= 3
15,000	40	<=20
15,000	40	<=50
15,000	50	<= 3
15,000	50	<=20
15,000	50	<=50
10,000	50	0 to 10
10,000	15	50 to 100

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Vehicle Barriers furnished shall in all respects be identical to the unit tested and certified [except for the width of the vehicle barrier, which is as indicated] [and] [except for bollards which have a diameter based on a required crash rating]. Crash test shall be performed and data compiled by an approved independent testing agency. Test vehicle shall not vault or penetrate the barrier during the test. The design and structural materials of the vehicle barrier furnished shall be the same as those used in the crash tested barrier.

#### 1.4 NAMEPLATES

Nameplate data shall be permanently attached to each vehicle barrier. The data shall be legibly marked on corrosion-resistant metal plates and shall



consist of at least the following:

- a. Manufacturer's name.
- b. Model number.
- c. Serial number.
- d. Date of manufacture.

#### 1.5 DELIVERY AND STORAGE

Components placed in storage shall be protected from the weather, humidity, and temperature variation, dirt and dust, or other contaminants. Structural materials shall be stored on sleepers or pallets and shall be protected from rust and objectionable materials such as dirt, grease, or oil.

#### 1.6 SPARE PARTS

A manufacturer's standard recommended spare parts package, with current unit prices and source of supply complete with detailed manuals on parts replacement, shall be provided with each barrier to facilitate 1 year of normal operation. Particular consideration shall be given to system components which are not readily available from local or commercial sources and which are critical to the operation of the system.

#### 1.7 MANUFACTURER'S SERVICES

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**NOTE: Delete this paragraph if a manufacturer's representative is not required in the project.**  
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Services of a manufacturer's representative who is experienced in the installation, adjustment, and operation of the equipment supplied shall be available. The representative shall supervise the installation, adjustment, and testing of the equipment.

### PART 2 PRODUCTS

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**Note: Hydraulic operated barrier systems shall contain synthetic biodegradable hydraulic fluid. The fluid shall be International Organization for Standardization (ISO) Grade 32 for cooler climates or ISO Grade 46 for temperate zones. Barriers for tropical or desert areas require a heavier grade, verify grade requirements with local suppliers. Based on barrier cycling and climate data, decide if a hydraulic fluid heater is required.**  
  
**Edit these paragraphs according to the barriers chosen.**  
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#### 2.1 RETRACTABLE BARRIERS

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NOTE: Coordinate with paragraph GENERAL REQUIREMENTS.

Based on the threat vehicle, state the height and width of retractable vehicle barrier required. The maximum tested width of approved barriers to date has not exceeded 3.66 m (144 inches). A minimum height of 711 mm (28 inches) is required. Consult manufacturer's literature for barrier heights.

The table below shows typical performance levels as a function of barrier height.

(Barrier Height Above Road Surface mm (in))	Average Barrier Height (mm) (in)	Typical Performance Level
787-1016 (31-40)	914 (36)	L3.0, K12
610-914 (24-36)	762 (30)	L2.0, K4 and varied lower levels
		L2.0, K4 and varied lower levels)

There are no known barriers capable of supporting loads larger than those indicated here and which will meet all other requirements found within this guide specification. These load limits are adequate for normal commercial truck traffic but will not support the Army's Heavy Equipment Transporter (HET) or similar vehicle. Overall design consideration must include providing alternate access for these vehicles if they have a valid reason for entering the secured area.

Federal and/or state EPA regulations may require that an oil/water separator be installed in the pit drainage system to ensure capture of any hydraulic fluid that may leak out of the system. If pit/vault type construction is required provisions will be made for drainage and connection to storm drainage system, or if no storm drain exists, a self-priming submersible sump pump of adequate capacity will be specified.

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When in the raised position, the total retractable barrier heights shall be no less than [ ] mm inches above the roadway surface and shall be [ ] mm inches wide. When in the lowered position, the retractable barrier shall extend no more than 16 mm 5/8 inch above the roadway surface.

Retractable barriers in the lowered position shall be capable of supporting a 142 kN 32,000 pound axle load or a 71 kN 16,000 pound wheel load. Design for this load shall be in accordance with AASHTO HB-17.

#### 2.1.1.1 Powered Retractable Barrier

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NOTE: Based on peak hourly volumes, fill in number of cycles per hour that the barrier will be required to function (maximum 300 complete up/down cycles per hour).

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The retractable barrier shall be capable of [\_\_\_\_\_] complete up/down cycles per hour. The retractable barrier motion shall be instantly reversible and shall be capable of raising the barrier from the lowered position to the raised position within 8 seconds during normal use, and within 2 seconds during an emergency. Also, the barrier shall be capable of being lowered from the raised position to the lowered position in not more than 3 seconds. [Retractable barrier shall withstand a [\_\_\_\_\_] kg pound vehicle at impact speed of [\_\_\_\_\_] km/hour mph with maximum barrier deflection or vehicle penetration of [\_\_\_\_\_] m feet].

#### 2.1.1.1 Failure Modes of Operation

The system shall be designed to remain in the last commanded position in the event of hydraulic, electrical, or mechanical failure. A manual pump, or other system, shall be included for operation of hydraulic barriers without power.

#### 2.1.1.2 Electric Motors

Unless otherwise indicated, electric motors shall have [drip-proof] [totally enclosed] [totally enclosed fan cooled] enclosures. All couplings, motor shafts, gears, and other moving parts shall be fully guarded in accordance with 29 CFR 1910 Subpart O. Guards shall be removable without disassembling the guarded unit. For multiple barriers operated from a single hydraulic unit it is highly recommended that the electric motor be 3-phase.

#### 2.1.1.3 System

The system shall be designed to maintain the barriers in the raised position, without inspection, for periods of time of up to 1 week. If a hydraulic system is used, it shall be equipped with pressure relief valves to prevent overpressure. The system shall not require continuous running of the motor to stay in the raised position, excluding the use of manual pinning to do so.

#### 2.1.1.4 Hydraulic Power Unit

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NOTE: Based on manufacturer's system layout the hydraulic platform unit should be located above ground. The unit should be placed on a reinforced concrete pad in a prefabricated weatherproof metal enclosure. Based on EPA requirements, provide a containment area; i.e., depressed floor or catch pan, to ensure capture of the total amount of hydraulic fluid within the hydraulic power unit. Access door or doors shall be provided to meet the maintenance requirements of the unit. The physical location of the unit should be on the protected side of the area.

The hydraulic oil viscosity must remain within its operating range, even after barrier non-use. If ambient temperature drops below -7 degrees C (20 degrees F) then hydraulic power unit shall be equipped with proper hydraulic oil, hydraulic oil

heater, insulated and heated hydraulic lines, and underground hydraulic oil lines in pipes. If ambient temperature exceeds 38 degrees C (100 degrees F) then the manufacture must supply efficient cooling and proper hydraulic oil for oil viscosity to remain within its operating range, even at constant heaviest use rate. If ambient temperature range requires the oil to be changed, the manufacturer must supply information on type of oil to be used and instructions for changing. Fill in the high and low air temperature of the area where the barrier will be installed.

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The hydraulic power unit shall contain synthetic biodegradable hydraulic fluid which maintains its viscosity operating range, even at constant heaviest use rate, for an ambient temperature range of [minus 7 to plus 66 degrees C 20 to 150 degrees F] [[\_\_\_\_\_] to [\_\_\_\_\_]]. A hydraulic fluid heater shall be provided so that the viscosity remains within its operating range if ambient temperatures below minus 7 degrees C 20 degrees F are expected. Buried hydraulic lines for the connection of the hydraulic power unit to the barrier shall be flexible or carbon steel pipe, or a combination of flexible and carbon steel pipe. Flexible and rigid hydraulic line working pressures shall exceed the maximum system relief pressure. [PVC pipe and fittings for burial of hydraulic lines shall be in accordance with ASTM D 3034 Type PS 46 with minimum pipe stiffness of 46.]

- a. Flexible hydraulic lines shall be in accordance with SAE J517.
- b. Rigid hydraulic lines shall be seamless carbon steel pipe in accordance with ASTM A 106/A 106M.

#### 2.1.1.5 Hydraulic Power Unit Enclosure

A NEMA Type 3R enclosure as specified in NEMA 250 shall be provided to enclose the hydraulic power unit. The enclosure shall be designed for easy removal of the hydraulic power unit and other accessories without complete removal of the enclosure. An access door with hinges and an inside and outside operable/lockable (exterior) door latch shall be provided. Equipment within the enclosure shall be placed and configured so that all periodic maintenance can be performed through the access door without removal of the equipment. The enclosure shall be equipped with weatherproof louver vents appropriately sized and located to dissipate internal heat generation.

#### 2.1.2 Manual Retractable Barriers

The manual barrier shall be capable of being raised and lowered by manual means such as levers or hydraulics requiring a maximum 267 N 60 pounds of force. The manual mechanism shall contain a locking pin which accepts a padlock for securing the barrier when it is in the "UP" position. Retractable barrier shall withstand a [\_\_\_\_\_] kg pound vehicle at impact speed of [\_\_\_\_\_] km/hour mph, with maximum barrier deflection or vehicle penetration of [\_\_\_\_\_] m feet. Barrier should be capable of being locked in the down position.

#### 2.2 RETRACTABLE BOLLARDS

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**NOTE: Coordinate with paragraph GENERAL  
REQUIREMENTS and paragraph RETRACTABLE BARRIERS.**

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The total bollard height when in the raised position shall be no less than 750 mm 30 inches above the roadway surface and shall have an outside diameter of no less than 200 mm 8 inches. A bollard system shall consist of a minimum of 3 bollards spaced no more than 915 mm 36 inches from centerline to centerline of bollards across a 3.0 m 10 foot roadway. Bollards in the lowered position shall be capable of supporting a 71 kN 16,000 pound wheel load each. Design for this load shall be in accordance with AASHTO HB-17. Retractable bollards shall withstand a [\_\_\_\_\_] kg pound vehicle at impact speed of [\_\_\_\_\_] km/hour mph with maximum bollard deflection or vehicle penetration of [\_\_\_\_\_] m feet.

#### 2.2.1 Powered Retractable Bollards

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**NOTE: Based on peak hourly volumes, fill in number  
of cycles per hour that the barrier will be required  
to function (maximum 300 complete up/down cycles per  
hour).**

\*\*\*\*\*

The retractable bollard shall be capable of [\_\_\_\_\_] complete up/down cycles per hour. Bollards shall be capable of being raised or lowered within a 3 to 15-second range during normal use and within 2.5 seconds for emergency operations.

##### 2.2.1.1 Failure Modes of Operation

The system shall be designed to prevent lowering of the barrier in the event of hydraulic, electrical, or mechanical failure. A manual pump, or other system, shall be included for operation of hydraulic and/or mechanical barriers without power.

##### 2.2.1.2 Electric Motors

Unless otherwise indicated, electric motors shall have [drip-proof] [totally enclosed] enclosures. For multiple barriers being operated from a hydraulic power unit it is highly recommended that the electric motor be 3-phase.

##### 2.2.1.3 System

The system shall be designed to maintain the barriers in the raised position, without inspection, for period of time of up to 1 week. If a hydraulic system is used, it shall be equipped with pressure relief valves to prevent overpressure.

##### 2.2.1.4 Hydraulic Power Unit

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**NOTE: Retain and edit or delete paragraph based on  
type of operator chosen.**

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The hydraulic power unit shall contain synthetic biodegradable hydraulic fluid which maintains its viscosity operating range, even at constant

heaviest use rate, for an ambient temperature range of [minus 7 to plus 66 degrees C 20 to 150 degrees F] [[\_\_\_\_\_] to [\_\_\_\_\_] ]. A hydraulic fluid heater shall be provided so that the viscosity remains within its operating range, if ambient temperatures below minus 7 degrees C 20 degrees F are expected. Buried hydraulic lines for the connection of the hydraulic power unit to the barrier shall be flexible or carbon steel pipe, or a combination of flexible and carbon steel pipe. Flexible and rigid hydraulic line working pressures shall exceed the maximum system relief pressure. [PVC pipe and fittings for burial of hydraulic lines shall be in accordance with ASTM D 3034 Type PS 46 with minimum pipe stiffness of 46.]

- a. Flexible hydraulic lines shall be in accordance with SAE J517.
- b. Rigid hydraulic lines shall be seamless carbon steel pipe in accordance with ASTM A 106/A 106M.

#### 2.2.1.5 Hydraulic Power Unit Enclosure

A NEMA Type 3R enclosure as specified in NEMA 250 shall be provided to enclose the hydraulic power unit. The enclosure shall be designed for easy removal of the hydraulic power unit and other accessories without complete removal of the enclosure. An access door with hinges and an inside and outside operable/lockable (exterior) door latch shall be provided. Equipment within the enclosure shall be placed and configured so that all periodic maintenance can be performed through the access door without removal of the equipment. The enclosure shall be equipped with weatherproof louver vents appropriately sized and located to dissipate internal heat generation.

#### 2.2.2 Manual Retractable Bollards

Manual bollards shall be capable of being raised and lowered utilizing a recessed handle on the top surface of the bollard or a manual hydraulic pump, either requiring a maximum 267 N 60 pounds of force. A mechanism, that is lockable, shall be provided to secure the bollard in either the full "UP" or full "DOWN" position.

### 2.3 CRASH GATE

The crash gate shall consist of steel buttresses anchored into the ground and an above grade assembly consisting of a heavy steel structure or a combination of heavy steel and structural aluminum capable of being opened and closed. The height of the gate shall be a minimum of [2.1] [\_\_\_\_\_] m [84] [\_\_\_\_\_] inches from the road surface to the top of the gate frame. The length shall close and protect a minimum [3.0] [\_\_\_\_\_] m [120] [\_\_\_\_\_] inch clear opening. The maximum clear opening between the gate frame and end posts, between the bottom of the gate and finished grade, and between any grill work shall be 75 mm 3 inches.

#### 2.3.1 Powered Crash Gate

The gate movement shall be controlled by [an electro-mechanical gate operator] [a hydraulic gate operator] consisting of an operator unit with required control circuits and operator station. The control and operating voltage shall be 24 vac (nominal) or, as an option 24 vdc. A remote control master station shall be capable of driving the gate at [[\_\_\_\_\_] m per second fpm] [[\_\_\_\_\_] degrees per second] for a swing gate. Unless otherwise indicated, motors shall have [drip-proof] [totally enclosed] enclosures. Crash gate shall withstand a 6804 kg 15,000 pound vehicle at impact speed of

[48] [64] [80] km/hour [30] [40] [50] mph, with maximum barrier deflection or vehicle penetration of [\_\_\_\_\_]m feet.

#### 2.3.1.1 Failure Mode of Operation

The system shall be designed to prevent opening of the crash gate in the event of electrical or mechanical failure. A disconnect system for the gate drive shall be provided to allow manual operation of the barrier in the event of a power outage.

#### 2.3.1.2 Hydraulic Power Unit

\*\*\*\*\*  
NOTE: Retain and edit or delete paragraph based on  
type of operator chosen. Coordinate with PART 2  
PRODUCTS.  
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The hydraulic power unit shall contain synthetic biodegradable hydraulic fluid which maintains its viscosity within its operating range, even at constant heaviest use rate, for an ambient temperature range of [minus 7 to plus 66 degrees C 20 to 150 degrees F] [[\_\_\_\_\_] to [\_\_\_\_\_] ]. A hydraulic fluid heater shall be provided so that the viscosity remains within its operating range if ambient temperatures below minus 7 degrees C 20 degrees F are expected. Buried hydraulic lines for the connection of the hydraulic power unit to the barrier shall be flexible or carbon steel pipe, or a combination of flexible and carbon steel. Flexible and rigid hydraulic line working pressures shall exceed the maximum system relief pressure. [PVC pipe and fittings for burial of hydraulic lines shall be in accordance with ASTM D 3034 Type PS 46 with minimum pipe stiffness of 46.]

- a. Flexible hydraulic lines shall be in accordance with SAE J517.
- b. Rigid hydraulic lines shall be seamless carbon steel pipe in accordance with ASTM A 106/A 106M.

#### 2.3.1.3 Hydraulic Power Unit Enclosure

A NEMA Type 3R enclosure as specified in NEMA 250 shall be provided to enclose the hydraulic power unit. The enclosure shall be designed for easy removal of the hydraulic power unit and other accessories without complete removal of the enclosure. An access door with hinges and an inside and outside operable/lockable (exterior) door latch shall be provided. Equipment within the enclosure shall be placed and configured so that all periodic maintenance can be performed through the access door without removal of the equipment. The enclosure shall be equipped with weatherproof louver vents appropriately sized and located to dissipate internal heat generation.

#### 2.3.2 Manual Crash Gate

The manual crash gate shall be capable of being hinged from either side. Hinge points of both buttresses shall each contain a locking pin with padlock acceptance for securing the crash gate in the closed position. The crash gate shall withstand a [4535 kg 10,000 pound] vehicle at impact speed of 80 km/hour 50 mph, with maximum gate deflection or vehicle penetration of 3 m 10 feet [6804 kg 15,000 pound] vehicle traveling at impact speed of [48] [64] [80] km/hour [30] [40] [50] mph, with a maximum gate deflection or vehicle penetration of up to 1 m 3 feet].

## 2.4 CRASH BEAM

\*\*\*\*\*

NOTE: Edit the paragraph for the crash barrier requirements. Department of State impact condition of a 6804 kg (15,000 pound) vehicle traveling at 48 km/hour (30 mph), 64 km/hour (40 mph), or 80 km/hour (50 mph) with penetration of less than 6 m (20 feet). Or Department of the Navy impact condition of a 4535 kg (10,000 pound) traveling at 24 km/hour (15 mph), with penetration of less than 3 m (10 feet).

\*\*\*\*\*

The crash beam shall be an above-grade assembly that, in the "DOWN" position, shall present a visible obstacle to approaching vehicles. The height of the barrier shall be a minimum of 750 mm 30 inches as measured from the roadway surface to the centerline of the crash beam. The crash beam shall be capable of blocking a minimum road width of [3.0] [\_\_\_\_\_] m [120] [\_\_\_\_\_] inches. The crash beam end shall contain a locking pin with padlock acceptance for securing the crash beam when it is in the "DOWN" position. Crash beam shall withstand a [6804 kg 15,000 pound vehicle traveling at [48] [64] [80] km/hour [30] [40] [50] mph, with maximum vehicle penetration of 6 m 20 feet] [4535 kg 10,000 pound vehicle at impact speed of 24 km/hour 15 mph, with a maximum vehicle penetration of 3 m 10 feet].

### 2.4.1 Powered Crash Beam

The crash beam shall be operated by means of a hydraulic power system. The crash beam shall be capable of being raised or lowered within an 8 to 15 second time range.

#### 2.4.1.1 Failure Mode of Operation

A disconnect system for the crash beam shall be provided to allow manual operation of the barrier in the event of an electrical or mechanical failure.

#### 2.4.1.2 Hydraulic Power Unit

\*\*\*\*\*

NOTE: Retain and edit or delete paragraph based on type of operator chosen.

\*\*\*\*\*

The hydraulic power unit shall contain synthetic biodegradable hydraulic fluid which maintains its viscosity operatin range, even at constant heaviest use rate, for an ambient temperature range of [minus 7 to plus 66 degrees C 20 to 150 degrees F] [[\_\_\_\_\_] to [\_\_\_\_\_] ]. A hydraulic fluid heater shall be provided so that the viscosity remains within its operating range if ambient temperatures below minus 7 degrees C 20 degrees F are expected. Buried hydraulic lines for the connection of the hydraulic power unit to the barrier shall be flexible or carbon steel pipe or a combination of flexible and carbon steel pipe. Flexible and rigid hydraulic line working pressures shall exceed the maximum system relief pressure. [PVC pipe and fittings for burial of hydraulic lines shall be in accordance with ASTM D 3034 Type PS 46 with minimum pipe stiffness of 46.]



- a. Flexible hydraulic lines shall be in accordance with SAE J517.
- b. Rigid hydraulic lines shall be seamless carbon steel pipe in accordance with ASTM A 106/A 106M.

#### 2.4.1.3 Hydraulic Power Unit Enclosure

A NEMA Type 3R enclosure as specified in NEMA 250 shall be provided to enclose the hydraulic power unit. The enclosure shall be designed for easy removal of the hydraulic power unit components and other accessories without complete removal of the enclosure. An access door with hinges and an inside and outside operable/lockable exterior door latch shall be provided. Equipment within the enclosure shall be placed and configured so that all periodic maintenance can be performed through the access door without removal of the equipment. The enclosure shall be equipped with weatherproof louver vents appropriately sized and located to dissipate internal heat generation.

#### 2.4.2 Manual Crash Beam

The crash beam shall be manually raised and lowered with the aid of a counterbalanced end requiring approximately 267 N 60 pounds of force.

### 2.5 PORTABLE RETRACTABLE BARRIER

The portable retractable barrier shall be transportable and capable of manual and/or electro-mechanical operation. When in the raised position, the total barrier heights shall be no less than [\_\_\_\_\_] mm inches above the roadway surface and shall be [\_\_\_\_\_] mm inches wide. The barrier shall be equipped with entrance/exit ramps when the barrier extends more than 16 mm 5/8 inch above the roadway surface. Retractable barriers in the lowered position shall be capable of supporting a 142 kN 32,000 pound axle load or a 71 kN 16,000 pound wheel load. Design for this load shall be accordance with AASHTO HB-17.

#### 2.5.1 Powered Portable Retractable Barrier

\*\*\*\*\*  
**NOTE: Based on peak hourly volumes, fill in number of cycles per hour that the barrier will be required to function (maximum 300 complete up/down cycles per hour).**  
 \*\*\*\*\*

The portable retractable barrier shall be capable of [\_\_\_\_\_] complete up/down cycles per hour. The retractable barrier motion shall be instantly reversible and shall be capable of raising the barrier from the lowered position to the raised position within 8 seconds during normal use, and within 2 seconds during an emergency. Also, the barrier shall be capable of being closed from the raised position to the lowered position in not more than 3 seconds. [Retractable barrier shall withstand a [\_\_\_\_\_] kg pound vehicle at impact speed of [\_\_\_\_\_] km/hour mph with maximum barrier deflection or vehicle penetration of [\_\_\_\_\_] m feet.] Portable retractable barrier, when impacted by a [\_\_\_\_\_] kg pound vehicle at impact speed of [\_\_\_\_\_] km/hour mph shall disable the vehicle and allow it to travel no more than 15.2 m 50 feet after impact. Portable power assisted retractable barriers shall be equipped with on and off ramps for smooth transition between surfaces when the barrier extends more than 16 mm 5/8 inch above the roadway surface.

#### 2.5.1.1 Failure Modes of Operation

The system shall be designed to prevent lowering of the barrier in the event of hydraulic, electric, or mechanical failure. A manual pump shall be included for operation of hydraulic and/or mechanical barriers without power.

#### 2.5.1.2 Electric Motors

Unless otherwise indicated, electric motors shall have [drip-proof] [totally enclosed] enclosures.

#### 2.5.1.3 System

The system shall be designed to maintain the barriers in the raised position, without inspection, for periods of time of up to 1 week. If a hydraulic system is used, it shall be equipped with pressure relief valves to prevent overpressure.

#### 2.5.1.4 Hydraulic Power Unit

The hydraulic power unit shall contain synthetic biodegradable hydraulic fluid which maintains its viscosity operating range, even at constant heaviest use rate, for an ambient temperature range of minus 7 to plus 66 degrees C 20 to 150 degrees F. A hydraulic fluid heater shall be provided so that the viscosity remains within its operating range if ambient temperatures below minus 7 degrees C 20 degrees F are expected. Flexible hydraulic lines shall be used for the connection of the hydraulic power unit to the barrier. Flexible hydraulic line working pressures shall exceed the maximum system relief pressure; flexible hydraulic lines shall be in accordance with SAE J517.

#### 2.5.2 Manual Retractable Portable Barriers

The manual barrier shall be capable of being raised and lowered by manual means such as levers or hydraulics requiring a maximum 267 N 60 pounds of force. The manual mechanism shall contain a locking pin which accepts a padlock for securing the barrier when it is in the "UP" position and shall also be capable of being locked in the "DOWN" position. Retractable barrier shall withstand a [ ] kg pound vehicle at impact speed of [ ] km/hour mph, with maximum barrier deflection or vehicle penetration of [ ] m feet.

#### 2.6 PORTABLE CRASH BEAM

The portable crash beam shall be an above-grade assembly that, in the "DOWN" position, shall present a visible obstacle to approaching vehicles. The height of the barrier shall be a minimum of 750 mm 30 inches as measured from the roadway surface to the centerline of the crash beam. The crash beam shall be capable of blocking a minimum road width of [3.0] [ ] m [120] [ ] inches. The crash beam end shall contain a locking pin with padlock acceptance for securing the crash beam when it is in the "DOWN" position. Crash beam shall withstand a 6804 kg 15,000 pound vehicle traveling at 48 km/hour 30 mph, with maximum vehicle penetration and/or barrier deflection of 6 m 20 feet.

#### 2.6.1 Powered Portable Crash Beam

The portable crash beam shall be operated by means of a hydraulic power system. The crash beam shall be capable of being raised or lowered within an 8 to 15 second time range.

##### 2.6.1.1 Failure Mode of Operation

A disconnect system for the portable crash beam shall be provided to allow manual operation of the barrier in the event of an electrical or mechanical failure.

##### 2.6.1.2 Hydraulic Power Unit

\*\*\*\*\*  
**NOTE: Retain and edit or delete paragraph based on  
type of operator chosen.**  
\*\*\*\*\*

The hydraulic power unit shall contain synthetic biodegradable hydraulic fluid which maintains its viscosity operating range, even at constant heaviest use rate, for an ambient temperature range of [minus 7 to plus 66 degrees C 20 to 150 degrees F] [[\_\_\_\_\_] to [\_\_\_\_\_]]. A hydraulic fluid heater shall be provided so that the viscosity remains within its operating range if ambient temperatures below minus 7 degrees C 20 degrees F are expected. Flexible hydraulic lines shall be used for the connection of the hydraulic power unit to the barrier. Flexible hydraulic line working pressures shall exceed the maximum system relief pressure; flexible hydraulic lines shall be in accordance with SAE J517.

##### 2.6.1.3 Hydraulic Power Unit Enclosure

A weather resistant enclosure shall be provided to enclose the hydraulic power unit. The enclosure shall be designed for easy removal of the hydraulic power unit components and other accessories without complete removal of the enclosure. An access door with hinges and an inside and outside operable lockable (exterior) door latch shall be provided. Equipment within the enclosure shall be placed and configured so that all periodic maintenance can be performed through the access door without removal of the equipment. The enclosure shall be equipped with weatherproof louver vents appropriately sized and located to dissipate internal heat generation.

#### 2.6.2 Manual Portable Crash Beam

The crash beam shall be manually operated by means of a counter balanced system requiring approximately 267 N 60 pounds of force.

#### 2.7 ELECTRICAL WORK

\*\*\*\*\*  
**NOTE: Designer will check with the user if a  
standby power source is required. If 1 is required,  
provide the appropriate guide specification.**  
\*\*\*\*\*

Motors, manual or automatic motor control equipment [except where installed in motor control centers] and protective or signal devices required for the operation specified herein shall be provided in accordance with Section

26 20 00 INTERIOR DISTRIBUTION SYSTEM. All field wiring for loop detectors, communication lines, and power circuits shall have surge protection. Any wiring required for the operation specified herein, but not shown on the electrical plans, shall be provided under this section in accordance with Sections [26 20 00 INTERIOR DISTRIBUTION SYSTEM] [and 33 70 02.00 10 ELECTRICAL DISTRIBUTION SYSTEM, UNDERGROUND].

## 2.8 CONTROL PANEL

\*\*\*\*\*  
NOTE: Delete reference to remote control panel if it is not applicable. Add to end of paragraph if signal light logic is required: "Logic shall be provided to coordinate the barricade and the traffic light."  
\*\*\*\*\*

A control panel and control circuit shall be provided to interface between all barrier control stations and the power unit. A control panel shall be provided for the inbound lanes and a separate one for the outbound lanes where the barriers are located. The control station is defined as the main control panel [and the remote control panel] as shown. The control circuit shall contain all relays, timers, and other devices or an industrial programmable controller programmed as necessary for the barrier operation. The control panel shall allow direct interface with auxiliary equipment such as card readers, remote switches, loop detectors, infrared sensors, and [sliding] [swinging] gate limit switches. Loop controllers shall not cause an automatic barrier raise following power loss or restoration. The enclosure shall be as indicated on the drawings. All device interconnect lines shall be run to terminal strips.

### 2.8.1 Voltage

The control circuit shall operate from a [120] [\_\_\_\_\_] volt [60] [50] Hz supply. The control circuit voltage shall be [12] [24] [\_\_\_\_\_] [ac] [dc] for all external control panels.

### 2.8.2 Main Control Panel

A main control panel shall be supplied to control barrier function. This panel shall have a key-lockable main switch with main power "ON" and panel "ON" lights. Buttons to raise and lower each [barrier] [set of barriers] shall be provided. Barrier "UP" and "DOWN" indicator lights shall be included for each [barrier] [set of barriers]. An emergency fast operate circuit (EFO) shall be operated from a push button larger than the normal controls and have a flip safety cover installed over the push button or toggle switch. The EFO shall also be furnished with an EFO-active light and reset button. [The main control panel shall have a key lockable switch to arm or disable the remote control panel. An indicator light shall show if the remote control panel is enabled.]

### 2.8.3 Remote Control Panel

\*\*\*\*\*  
NOTE: A remote control panel will be required at the entry control point where the barriers are located if a main control panel is required at the main security command center.  
\*\*\*\*\*

A remote control panel, one panel for the inbound lane(s) and a separate panel for the outbound lane(s), shall have a panel "ON" light that is lit when enabled by a key lockable switch on the main control panel. Buttons to raise and lower each barrier shall be provided. Barrier "UP" and "DOWN" indicator lights shall be included for each barrier. The EFO shall be operated from a push button larger than the normal controls and have a flip safety cover installed over the push button or toggle switch. Activation of either EFO will operate all barriers. The EFO shall be interconnected with an EFO-active light. When the remote control panel EFO is pushed, operation of the barrier will not be possible from this panel until reset at the main control panel.

## 2.9 MISCELLANEOUS EQUIPMENT

### 2.9.1 Safety Equipment

#### 2.9.1.1 Barrier Systems Sensors

\*\*\*\*\*  
NOTE: Safety equipment identified in items "b." and "c." below, and subparagraphs "Warning Annunciators" and "Vehicle Barrier Vertical Arm Gate (Traffic Arm)" are required at installation access control points. If active vehicle barriers are used for other applications, edit the subparagraphs below accordingly.  
\*\*\*\*\*

The barrier system sensors shall consist of the following:

- a. Suppression Loops - Two inductive loops whose outputs shall be used to prevent barriers raising when a vehicle is within a prescribed distance of the barrier. The output of the loops shall override all barrier rise signals until one second after a vehicle clears the suppression loop.
- b. Speed Loops - Two inductive loops whose output shall be used to signal the barrier controller of a vehicle approaching at a speed greater than the posted speed (11.2 m/sec 25 mph or less (recommended)). The speed loops shall cause the barrier control panel to annunciate a warning sound alerting the guard to make a decision as to whether the barrier should be raised or not.
- c. Wrong Way Loops - Two inductive loops whose output shall be used to signal the barrier control panel to annunciate a warning sound if a vehicle is attempting to enter the facility through the exit lane. The warning sound will alert the guard to make a decision as to whether the barrier should be raised or not.

The sensors shall be compatible with the barrier controller and shall function as part of a complete barrier control system.

#### 2.9.1.2 Traffic Lights

\*\*\*\*\*  
NOTE: Designer must verify that vehicles using a gate with a barrier will be able to see the barrier position or the traffic lights. Semitrucks may

require a painted stop line or a traffic arm versus a higher mounted traffic light to ensure the lights or barrier can be seen by all vehicles.

\*\*\*\*\*

Red/yellow 200 mm 8 inch traffic lights shall be supplied for each entrance and exit to alert motorists of the barrier position. Traffic lights are not required for manual barriers. The yellow flashing light shall indicate that the barrier is fully open. All other positions shall cause the light to show red. Brackets shall be supplied to allow the light to be mounted a minimum 1.4 m 4.5 feet above the roadway pavement on a 90 mm 3.5 inch outside diameter metal post [or mounted directly on the crash gate].

#### 2.9.2 Warning Annunciator

Provide a warning annunciator built into the barrier control panel that produces a pulsing audible sound when the speed loop detects a vehicle entering the facility with excess speed. Provide a warning annunciator built into the barrier control panel that produces a continuous sound whenever a wrong way loop detects a vehicle entering from the exit. The warning annunciator shall sound until a warning annunciator silence reset button is pressed.

#### 2.9.3 Heater

\*\*\*\*\*

NOTE: Retain or delete paragraph based on climatic conditions.

\*\*\*\*\*

A waterproof barrier heater with a thermostat control and NEMA 4 junction box connection point shall be provided for de-icing and snow melting. The heater shall provide barrier operation to an ambient temperature of minus 40 degrees C minus 40 degrees F. For retractable bollards, a 250-watt heater shall be provided for each bollard.

#### 2.9.4 Signage

\*\*\*\*\*

NOTE: Load limit signs based on allowable single axle loads for highways of 80 kN (18,000 pounds) and maximum tandem axle loads of 142 kN (32,000 pounds) are required for subsurface vehicle barriers, except bollards, at entry control points (ECPs). Signage shall conform to FHWA SA-89-006.

\*\*\*\*\*

Signage shall read "Axle Weight Limit 9 Tons" and shall conform to FHWA SA-89-006 sign (R12.2).

#### 2.9.5 Vertical Arm Gates (Traffic Arms)

\*\*\*\*\*

NOTE: Edit the traffic arm location based on design requirements.

\*\*\*\*\*

Vertical arm gates shall have an opening and closing time of less than or equal to 5 seconds. The gates shall be capable of 500 duty cycles per hour

as a minimum. Gate shall operate the arm through 90 degrees. Gate operators shall be supplied with single phase 120 volt motors. [Each entry lane shall be provided with a vertical arm gate.] Each gate shall be capable of being operated from a remote open-close push button station [in each guard booth and the gatehouse for the respective entry lane]. Gates shall have a hand-crank, or other means, which will allow manual operation during power failures. Gate arms shall be constructed out of wood, steel, fiberglass, or aluminum, as specified by the manufacturer for the given lengths as shown on the drawings. Gate arms shall be covered with 406 mm 16 inch wide reflectorized red and white sheeting. Each gate shall be furnished with a spare gate arm. Gate operator cabinets shall be constructed of galvanized steel, or aluminum and shall be painted manufacturers standard color as approved. Each gate operator shall be provided with an obstruction detector that will automatically reverse the gate motor when an obstruction is detected. The obstruction detector shall be any of the following 3 types: An electronic loop vehicle detector buried in the road, a photocell electric eye mounted on the gate operator, or a safety strip mounted on the lower edge of the arm. The detector system shall be automatically deactivated when the arm reaches the fully lowered position. Slab size and anchorage for gate operator shall be per manufacturer requirements.

#### 2.9.6 Vehicle Barrier Vertical Arm Gate (Traffic Arm)

A traffic arm, as a separate piece of equipment, will be included with each non-portable active vehicle barrier as part of the barrier safety operating system. This traffic arm shall automatically deploy (close) when the emergency up button is activated and open when the vehicle barrier is reset. This traffic arm will not be equipped with an automatic obstruction detector.

#### 2.10 FINISH

Surfaces shall be painted in accordance with requirements of Section 09 90 00 PAINTS AND COATINGS. The roadway plate shall have a nonskid surface painted white with reflective red [100] [150] mm [4] [6] inch wide red reflective stripes 100 mm 4 inches apart. The barrier front shall be painted white and have [100] [150] mm [4] [6] inch wide reflective red stripes 100 mm 4 inches apart. The diagonal striping should point down and outward from the center of the device. Bollards shall be painted white with [50] [75] mm [2] [3] inch wide reflective red diagonal stripes. The barrier crash gate shall be painted as specified by purchaser and the crash beam shall be painted white with 75 mm 3 inch wide reflective red diagonal stripes.

#### 2.11 CONCRETE

The concrete shall conform to Section [03 31 00.00 10 CAST-IN-PLACE STRUCTURAL CONCRETE] [03 30 00.00 20 CAST-IN-PLACE CONCRETE].

#### 2.12 WELDING

Welding shall be in accordance with AWS D1.1/D1.1M.

#### 2.13 PAVEMENT

\*\*\*\*\*

**NOTE: Edit this paragraph to provide the  
specification Sections required, depending on the**

type of the existing pavement to be matched.

\*\*\*\*\*

After placement of the vehicle barrier, the pavement sections shall be replaced to match the section and depth of the surrounding pavement. Pavement shall be warped to match the elevations of existing pavement. Positive surface drainage, away from the vehicle barrier, shall be provided by pavement slope.

### PART 3 EXECUTION

#### 3.1 INSTALLATION

Installation shall be in accordance with manufacturers instructions and in the presence of a representative of the manufacturer. Manufacturer's representative shall be experienced in the installation, adjustment, and operation of the [equipment](#) provided. The representative shall also be present during adjustment and testing of the equipment.

#### 3.2 HYDRAULIC LINES

Buried hydraulic lines shall be placed in polyvinyl chloride (PVC) sleeves. Positive drainage shall be provided from the hydraulic power unit to the barrier for drainage of condensation within the PVC sleeve.

#### 3.3 PIT DRAINAGE

\*\*\*\*\*

NOTE: Edit this paragraph for drainage requirements. If soil characteristic and/or climate dictates another solution, then this should be considered and edited into this paragraph. Provide self-priming sump pump with capacity and power requirements if one is required. Delete this paragraph if pit/vault type construction is not required. Federal and/or State requirements may require an oil/water separator be installed in the pit drainage to ensure capture of any hydraulic fluid that may leak out of the system.

\*\*\*\*\*

A drain connection [and oil/water separator] shall be provided in each barrier that requires pit/vault type construction. Hookups between the storm drains shall be made. [The self-priming sump pump shall have the capacity to remove [\_\_\_\_\_] [cubic meters per second](#) [gallons per minute](#).]

#### 3.4 ELECTRICAL

All control power wiring requiring compression terminals shall use ring-style terminals. Terminals and compression tools shall conform to [UL 486A-486B](#). Roundhead screws and lockwashers shall be used to provide vibration-resistant connections. Connections between any printed circuit cards and the chassis shall be made with screw connections or other locking means to prevent shock or vibration separation of the card from its chassis. The electrical power supply breaker for the hydraulic power unit shall be capable of being locked in the power on and power off positions.



### 3.5 FIELD TESTING

\*\*\*\*\*  
NOTE: Edit paragraph accordingly for hydraulic or  
manual vehicle barrier.  
\*\*\*\*\*

Upon completion of construction, a field test shall be performed for each vehicle barrier. The test shall include raising and lowering the barrier, both electrically and manually, through its complete range of operation. Each vehicle barrier shall then be continuously cycled for not less than 30 minutes to test for heat build-up in the hydraulic system. The Contracting Officer shall be notified at least 7 days prior to the beginning of the field test. The Contractor shall furnish all equipment and make all necessary corrections and adjustments prior to tests witnessed by the Contracting Officer. Any conditions that interfere with the proper operation of the barrier disclosed by the test shall be corrected at no additional cost to the Government. Adjustments and repairs shall be done by the Contractor under the direction of the Contracting Officer. After adjustments are made to assure correct functioning of components, applicable tests shall be completed.

### 3.6 FIELD TRAINING

\*\*\*\*\*  
NOTE: For electrical/hydraulic option, select 8  
hour requirement. For the manual option, select the  
1-hour requirement.  
\*\*\*\*\*

A field training course shall be provided for designated operating staff members. Training shall be provided for a total period of not less than [8 hours] [1 hour] of normal working time and shall start after the system is functionally complete but prior to final acceptance tests. Field training shall cover all of the items contained in the [operating and maintenance instructions](#).

-- End of Section --