U.S. Department
of Transportation

**Federal Aviation
Administration**

Advisory Circular

Subject: Engineered Materials Arresting Systems (EMAS) for Aircraft Overruns

Date: 9/30/2005
Initiated by: AAS-100

AC No: 150/5220-22A
Change:

1. PURPOSE. This advisory circular (AC) contains standards for the planning, design, installation, and maintenance of Engineered Materials Arresting Systems (EMAS) in runway safety areas (RSA). Engineered Materials means high energy absorbing materials of selected strength, which will reliably and predictably crush under the weight of an aircraft.

2. CANCELLATION. This AC cancels AC 150/5220-22, *Engineered Materials Arresting Systems (EMAS) for Aircraft Overruns*, dated August 28, 1998.

3. BACKGROUND. Aircraft can and do overrun the ends of runways, sometimes with devastating results. An overrun occurs when an aircraft passes beyond the end of a runway during an aborted takeoff or while landing. Data on aircraft overruns over a 12-year period (1975 to 1987) indicate that approximately 90% of all overruns occur at exit speeds of 70 knots or less (Reference 7, Appendix 4) and most come to rest between the extended runway edges within 1000 feet of the runway end (Reference 6, Appendix 4).

To minimize the hazards of overruns, the Federal Aviation Administration (FAA) incorporated the concept of a safety area beyond the runway end into airport design standards. To meet the standards, the safety area must be capable, under normal (dry) conditions, of supporting the occasional passage of aircraft that overrun the runway without causing structural damage to the aircraft or injury to its occupants. The safety area also provides greater accessibility for emergency equipment after an overrun incident. There are many runways, particularly those constructed prior to the adoption of the safety area standards, where natural obstacles, local development, and/or environmental constraints, make the construction of a standard safety area impracticable. There have been accidents at some of these airports where the ability to stop an overrunning aircraft within the runway safety area would have prevented major damage to aircraft and/or injuries to passengers.

Recognizing the difficulties associated with achieving a standard safety area at all airports, the FAA undertook research programs on the use of various materials for arresting systems. These research programs, as well as, evaluation of actual aircraft overruns into an EMAS have demonstrated its effectiveness in arresting aircraft overruns.

4. APPLICATION. Runway safety area standards cannot be modified or waived. The standards remain in effect regardless of the presence of natural or man-made objects or surface conditions that might create a hazard to aircraft that overrun the end of a runway. A continuous evaluation of all practicable alternatives for improving each sub-standard RSA is required. FAA Order 5200.8, *Runway Safety Area Program*, explains the evaluation process.

FAA Order 5200.9, *Financial Feasibility and Equivalency of Runway Safety Area Improvements and Engineered Material Arresting Systems*, is used in connection with FAA Order 5200.8 to determine the best practicable and financially feasible alternative for an RSA improvement.

The FAA does not require an airport sponsor to reduce the length of a runway or declare its length to be less than the actual pavement length to meet runway safety area standards if there is an operational impact to the airport. An example of an operational impact would be an airport's inability to accommodate its current or planned aircraft fleet. Under these circumstances, installing an EMAS is another way of enhancing safety.

A standard EMAS provides a level of safety that is generally equivalent to a full RSA built to the dimensional standards in AC 150/5300-13, *Airport Design*. It also provides an acceptable level of safety for undershoots.

The FAA recommends the guidelines and standards in this AC for the design of EMAS. In general, this AC is not mandatory and does not constitute a regulation. It is issued for guidance purposes and to outline a method of compliance. However, use of these guidelines is mandatory for an airport sponsor installing an EMAS funded under Federal grant assistance programs or on an airport certificated under Title 14 Code of Federal Regulations (CFR) Part 139, *Certification of Airports*. Mandatory terms such as "shall" or "must" used herein apply only to those who seek to demonstrate compliance by use of the specific method described by this AC.

If an airport sponsor elects to follow an alternate method, the alternate method must have been determined by the FAA to be an acceptable means of complying with this AC, the runway safety area standards in AC 150/5300-13, and 14 CFR Part 139.

5. RELATED READING MATERIAL. Appendix 4, Related Reading Material, contains a list of documents with supplemental material relating to EMAS. These documents contain information on materials evaluated, as well as design, construction, and testing procedures utilized. Testing and data generated under these FAA studies may be used as input to an EMAS design without additional justification.

6. PLANNING CHARTS. The figures included in Appendix 2, Planning Charts, are for planning purposes only. They are intended as a preliminary screening tool and are not sufficient for final design. Final design must be customized for each installation. The figures illustrate estimated EMAS stopping distance capabilities for various aircraft types. The design used in each chart is optimized specifically for the aircraft noted on the chart. Charts are based on standard design conditions, i.e. 75-foot set-back, no reverse thrust, and poor braking (0.25 braking friction coefficient).

a. Example 1. Assume a runway with a DC-9 (or similar) as the design aircraft. Figure A2-1 shows that an EMAS 400 feet in length (including a 75-foot set-back) is capable of stopping a DC-9 within the confines of the system at runway exit speeds of up to 75 knots.

b. Example 2. Assume the same runway, but assume the design aircraft is a DC-10 (or similar). Figure A2-2 shows an EMAS of the same length, but designed for larger aircraft, can stop the DC-10 within the confines of the system at runway exit speeds of up to 62 knots.

7. PRELIMINARY PLANNING. Follow the guidance in FAA Orders 5200.8 and 5200.9 to determine practicable, financially feasible alternatives for RSA improvements. Additional cost and performance information for EMAS options to consider in the analysis can be obtained from the EMAS manufacturer.

8. SYSTEM DESIGN REQUIREMENTS. For purposes of design, the EMAS can be considered fixed by its function and frangible since it is designed to fail at a specified impact load. An aircraft arresting system such as EMAS is exempt from the requirements of 14 CFR Part 77, *Objects Affecting Navigable Airspace.* When EMAS is the selected option to upgrade a runway safety area, it is considered to meet the safety area requirements of 14 CFR Part 139. The following system design requirements must prevail for all EMAS installations:

a. Concept. An EMAS is designed to stop an overrunning aircraft by exerting predictable deceleration forces on its landing gear as the EMAS material crushes. It must be designed to minimize the potential for structural damage to aircraft, since such damage could result in injuries to passengers and/or affect the predictability of deceleration forces. An EMAS should be design for a 20-year service life.

b. Location. An EMAS is located beyond the end of the runway and centered on the extended runway centerline. It will usually begin at some setback distance from the end of the runway to avoid damage due to jet blast and undershoots (Figure A1-2, Appendix 1). This distance will vary depending on the available area and the EMAS materials. Where the area available is longer than required for installation of a standard EMAS designed to stop the design aircraft at an exit speed of 70 knots, the EMAS should be placed as far from the runway end as practicable. Such placement decreases the possibility of damage to the system from short overruns or undershoots and results in a more economical system by considering the deceleration capabilities of the existing runway safety area.

The resulting runway safety area must provide adequate protection for aircraft that touch down prior to the runway threshold (undershoot). Adequate protection is provided by either: (1) providing at least 600 feet (or the length of the standard runway safety area, whichever is less) between the runway threshold and the far end of the EMAS bed if the approach end of the runway has vertical guidance or (2) providing the full length standard runway safety area when no vertical guidance is provided.

An EMAS is not intended to meet the definition of a stopway as provided in AC 150/5300-13. The runway safety area and runway object free area lengths begin at a runway end when a stopway is not provided. When a stopway is provided, these lengths begin at the stopway end (AC 150/5300-13).

The airport sponsor, EMAS manufacturer, and the appropriate FAA Regional Airports Division/Airport District Office (ADO) should consult regarding the EMAS location to determine the appropriate location beyond the end of the runway for the EMAS installation for a specific runway.

c. Design Method. An EMAS design must be supported by a validated design method that can predict the performance of the system. The design (or critical) aircraft is defined as that aircraft using the associated runway that imposes the greatest demand upon the EMAS. This is usually, but not always, the heaviest/largest aircraft that regularly uses the runway. EMAS performance is dependent not only on aircraft weight, but landing gear configuration and tire pressure. In general, use the maximum take-off weight (MTOW) for the design aircraft. However, there may be instances where less than the MTOW will require a longer EMAS. All configurations should be considered in optimizing the EMAS design. To the extent practicable, however, the EMAS design should consider both the aircraft that imposes the greatest demand upon the EMAS and the range of aircraft expected to operate on the runway. In some instances, this composite design aircraft may be preferable to optimizing the EMAS for a single design aircraft. Other factors unique to a particular airport, such as available RSA and air cargo operations, should also be considered in the final design. The airport sponsor, EMAS manufacturer, and the appropriate FAA Regional Airports Division/ADO should consult regarding the selection of the design aircraft that will optimize the EMAS for a specific airport.

The design method must be derived from field or laboratory tests. Testing may be based either on passage of an actual aircraft or an equivalent single wheel load through a test bed. The design must consider multiple aircraft parameters, including but not limited to allowable aircraft gear loads, gear configuration, tire contact pressure, aircraft center of gravity, and aircraft speed. The model must calculate imposed aircraft gear loads, g-forces on aircraft occupants, deceleration rates, and stopping distances within the arresting system. Any rebound of the crushed material that may lessen its effectiveness must also be considered.

d. Operation. The EMAS must be a passive system.

e. Width. The minimum width of the EMAS must be the width of the runway (plus any sloped area as necessary—see 8 (h) below).

f. Base. The EMAS must be constructed on a paved surface capable of supporting the occasional passage of the critical design aircraft using the runway and fully loaded Aircraft Rescue and Fire Fighting (ARFF) vehicles without deformation of the base surface or structural damage to the aircraft or vehicles. It must be designed to perform satisfactorily under all local weather, temperature, and soil conditions. It must provide sufficient support to facilitate removal of the aircraft from the EMAS. Full strength runway pavement is not required. Pavement suitable for shoulders and blast pads is suitable as an EMAS base. AC 150/5300-13 provides recommendations on pavement for shoulders and blast pads. State highway specifications may also be used.

g. Entrance Speed. To the maximum extent possible, the EMAS must be designed to decelerate the design aircraft expected to use the runway at exit speeds of 70 knots (approach category C and D aircraft) without imposing loads that exceed the aircraft's design limits, causing major structural damage to the aircraft or imposing excessive forces on its occupants. Contact the FAA's Airport Engineering Division (AAS-100) at 202-267-7669 for guidance when other than approach category C and D aircraft is proposed for the EMAS design. Standard design conditions are no reverse thrust and poor braking (0.25 braking friction coefficient).

Generally, when there is insufficient RSA available for a standard EMAS, the EMAS must be designed to achieve the maximum deceleration of the design aircraft within the available runway safety area. However, a 40-knot minimum exit speed should be used for the design of a non-standard EMAS. For design purposes, assume the aircraft has all of its landing gear in full contact with the runway and is traveling within the confines of the runway and parallel to the runway centerline upon overrunning the runway end.

The airport sponsor, EMAS manufacturer, and the appropriate FAA Regional Airports Division/ADO should consult regarding the selection of the appropriate design entrance speed for the EMAS installation.

Note that current EMAS models are not as accurate for aircraft with a maximum take-off weight less than 25,000 pounds.

h. Aircraft Evacuation. The EMAS must be designed to enable safe ingress and egress as well as movement of ARFF equipment (not necessarily without damage to the EMAS) operating during an emergency. If the EMAS is to be built above existing grade, sloped areas sufficient to allow the entrance of ARFF vehicles from the front and sides must be provided. Provision for access from the back of the EMAS may be provided if desirable. Maximum slopes must be based on the EMAS material and performance characteristics of the airport's ARFF equipment.

i. Maintenance Access. The EMAS must be capable of supporting regular pedestrian traffic for the purposes of maintenance of the arresting material and co-located navigation aids without damage to the surface of the EMAS bed. An EMAS is not intended to support vehicular traffic for maintenance purposes.

j. Undershoots. The EMAS must not cause control problems for aircraft undershoots which touch down in the EMAS bed. Fulfillment of this requirement may be based exclusively on flight simulator tests. The tests will establish the minimum material strength and density that does not cause aircraft control problems during an undershoot. Materials whose density and strength exceeds these minimums will be deemed acceptable.

k. Navigation Aids. The EMAS must be constructed to accommodate approach lighting structures and other approved facilities within its boundaries. It must not cause visual or electronic interference with any air navigation aids. All navigation aids within the EMAS must be frangible as required by 14 CFR Part 139. To meet the intent of this regulation, approach light standards must be designed to fail at two points. The first point of frangibility must be three inches or less above the top of the EMAS bed. The second point of frangibility must be three inches or less above the expected residual depth of the EMAS bed after passage of the design aircraft. As a part of the EMAS design, the EMAS manufacturer must provide the expected residual depth to allow the determination of this second frangibility point.

l. Drainage. The EMAS must be designed to prevent water from accumulating on the surface of the EMAS bed, the runway or the runway safety area. The removal and disposal of water, which may hinder any activity necessary for the safe and efficient operation of the airport, must be in accordance with AC 150/5320-5, *Airport Drainage.*

The EMAS design must consider ice accumulation and/or snow removal limitations/requirements dictated by the project locale. Requirements/limitations must be addressed in the approved inspection and maintenance program discussed in paragraph 14 and Appendix 3.

m. Jet Blast. The EMAS must be designed and constructed so that it will not be damaged by expected jet blast.

n. Repair. The EMAS must be designed for repair to a usable condition within 45 days of an overrun by the design aircraft at the design entrance speed. Note that this is a design requirement only.

An EMAS bed damaged due to an incident (overrun/undershoot, etc.) must be repaired in a timely manner. The undamaged areas of the EMAS bed must be protected from further damage until the bed is repaired.

9. MATERIAL QUALIFICATION. The material comprising the EMAS must have the following requirements and characteristics:

a. Material Strength and Deformation Requirements. Materials must meet a force vs. deformation profile within limits having been shown to assure uniform crushing characteristics, and therefore, predictable response to an aircraft entering the arresting system.

b. Material Characteristics. The materials comprising the EMAS must:

(1) Be water-resistant to the extent that the presence of water does not affect system performance.

(2) Not attract vermin, birds, wildlife or other creatures.

(3) Be non-sparking.

(4) Be non-flammable.

(5) Not promote combustion.

(6) Not emit toxic or malodorous fumes in a fire environment after installation.

(7) Not support unintended plant growth with proper application of herbicides.

(8) Exhibit constant strength and density characteristics during all climatic conditions within a temperature range appropriate for the locale.

(9) Be resistant to deterioration due to:

(a) Salt.

(b) Approved aircraft and runway deicing fluids.

(c) Aircraft fuels, hydraulic fluids, and lubricating oils.

(d) UV resistant.

(e) Water.

(f) Freeze/thaw.

(g) Blowing sand and snow.

(h) Paint.

10. Material Conformance Requirements. An EMAS manufacturer must establish a material sampling and testing program to verify that all materials are in conformance with the initial approved material force versus deformation profile established under paragraph 9.a. Materials failing to meet these requirements must not be used.

The initial sampling and testing program must be submitted to and approved by the FAA, Office of Airport Safety and Standards for each design method found by the FAA to be an acceptable means of complying with this AC. Once approved, the program may be used for subsequent projects.

11. DESIGN PROPOSAL SUBMITTAL. The EMAS design must be prepared by the design engineer and the EMAS manufacturer for the airport sponsor. The airport sponsor must submit the EMAS design through the responsible FAA Airports Region/District Office, to the FAA, Office of Airport Safety and Standards, for review and approval. The EMAS design must be certified as meeting all the requirements of this AC and the submittal must include all design assumptions and data utilized in its development as well as proposed construction procedures and techniques. The EMAS design must be submitted at least 45 days prior to the bid opening date for the project.

12. QUALITY ASSURANCE (QA) PROGRAM. A construction quality assurance program must be implemented to ensure that installation/construction is in accordance with the approved EMAS design. The construction contractor and EMAS manufacturer prepare the construction QA program for the airport sponsor. The airport sponsor must submit the construction QA program to the responsible FAA Airports Region/District Office for approval 14 days prior to the project notice to proceed.

13. MARKING. An EMAS must be marked with yellow chevrons as an area unusable for landing, takeoff, and taxiing in accordance with AC 150/5340-1, *Standards for Airport Markings.* Paint application should be in accordance with the EMAS manufacturers' recommendations for the EMAS system.

14. INSPECTION AND MAINTENANCE. The EMAS manufacturer must prepare an inspection and maintenance program for the airport sponsor for each EMAS installation. The airport sponsor must submit the program to the responsible FAA Airports Region/District Office for approval prior to final project acceptance. The airport sponsor must implement the approved inspection and maintenance program. The program must include any necessary procedures for inspection, preventive maintenance and unscheduled repairs, particularly to weatherproofing layers. Procedures must be sufficiently detailed to allow maintenance/repair of the EMAS bed with the airport sponsor's staff. The program must include appropriate records to verify that all required inspections and maintenance have been performed by the airport sponsor and/or EMAS manufacturer. These records must be made available to the FAA upon request. Appendix 3, Inspection and Maintenance Program, outlines the basic requirements of an EMAS inspection and maintenance program.

Airport personnel must be notified that the EMAS is designed to fail under load and that precautions should be taken when activities require personnel to be on, or vehicles and personnel to be near, the EMAS.

15. AIRCRAFT RESCUE AND FIRE FIGHTING (ARFF).

a. Access. As required by paragraph 8 (h), an EMAS is designed to allow movement of typical ARFF equipment operating during an emergency. However, as the sides of the system are typically steeply sloped, and the system will be severely rutted after an aircraft arrestment, ARFF vehicles so equipped should be shifted into all-wheel-drive prior to entering and maneuvering upon an EMAS.

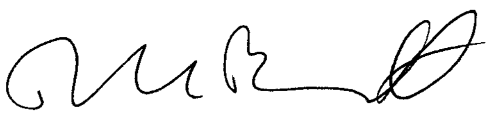
b. Tactics. Any fire present after the arrestment of an aircraft will be three-dimensional due to the rutting and breakup of the EMAS material. A dual-agent attack and/or other tactics appropriate to this type of fire should be employed.

16. NOTIFICATION. Upon installation of an EMAS, its length, width, and location must be included as a remark in the Airport/Facility Directory (AFD). To assure timely publication, the airport sponsor must forward the required information to the FAA Aeronautical Information Services (AIS) as soon as possible, but not later than the “cut-off” dates listed in the AFD, for publication on the desired effective date. (The AIS address and cut-off dates are listed on the inside front cover of the AFD.) The airport sponsor must also notify the appropriate FAA Regional Airports Division/ADO.

The following is an example of a typical entry:

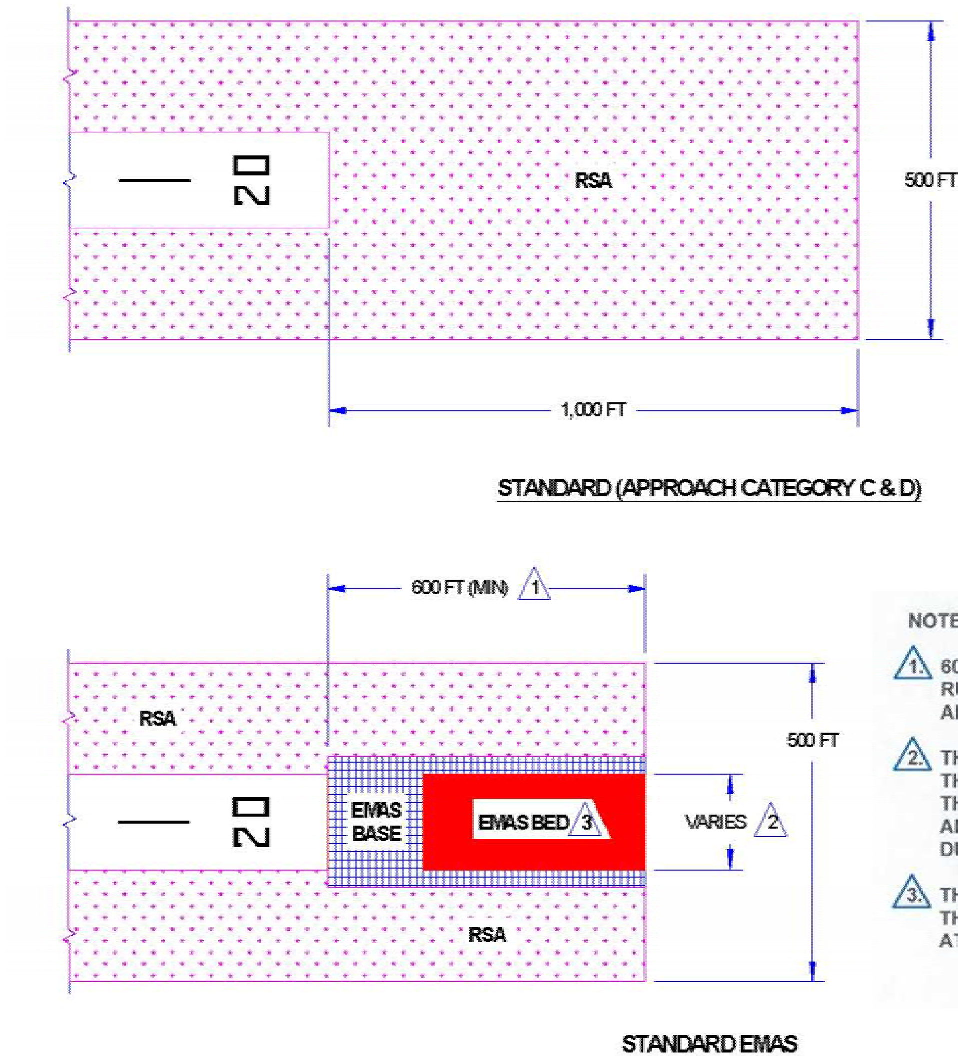
- “Engineered Materials Arresting System, 400’L x 150’W, located at departure end of runway 16.”

When an EMAS is damaged due to an overrun or determined to be less than fully serviceable, a Notice to Airmen (NOTAM) must be issued to alert airport users of the reduced performance of the EMAS.



DAVID L. BENNETT
Director of Airport Safety and Standards

APPENDIX 1. STANDARD EMAS AND TYPICAL SECTIONS.



NOTES:

1. 600 FEET MINIMUM REDUCTION APPLIES ONLY TO RUNWAY ENDS WITH VERTICAL GUIDANCE FOR APPROACHES.
2. THE WIDTH OF THE EMAS BED IS THE WIDTH OF THE RUNWAY PLUS ANY SLOPED AREA ALONG THE SIDES REQUIRED FOR SAFE INGRESS/EGRESS AND MOVEMENT OF ARFF EQUIPMENT OPERATING DURING AN EMERGENCY.
3. THE EMAS BED IS DESIGNED TO STOP THE DESIGN AIRCRAFT THAT EXITS THE END OF THE RUNWAY TRAVELING AT 70 KNOTS.

FIGURE A1-1. STANDARD EMAS INSTALLATION PROVIDES A LEVEL OF SAFETY THAT IS GENERALLY EQUIVALENT TO A STANDARD RUNWAY SAFETY AREA (RSA).

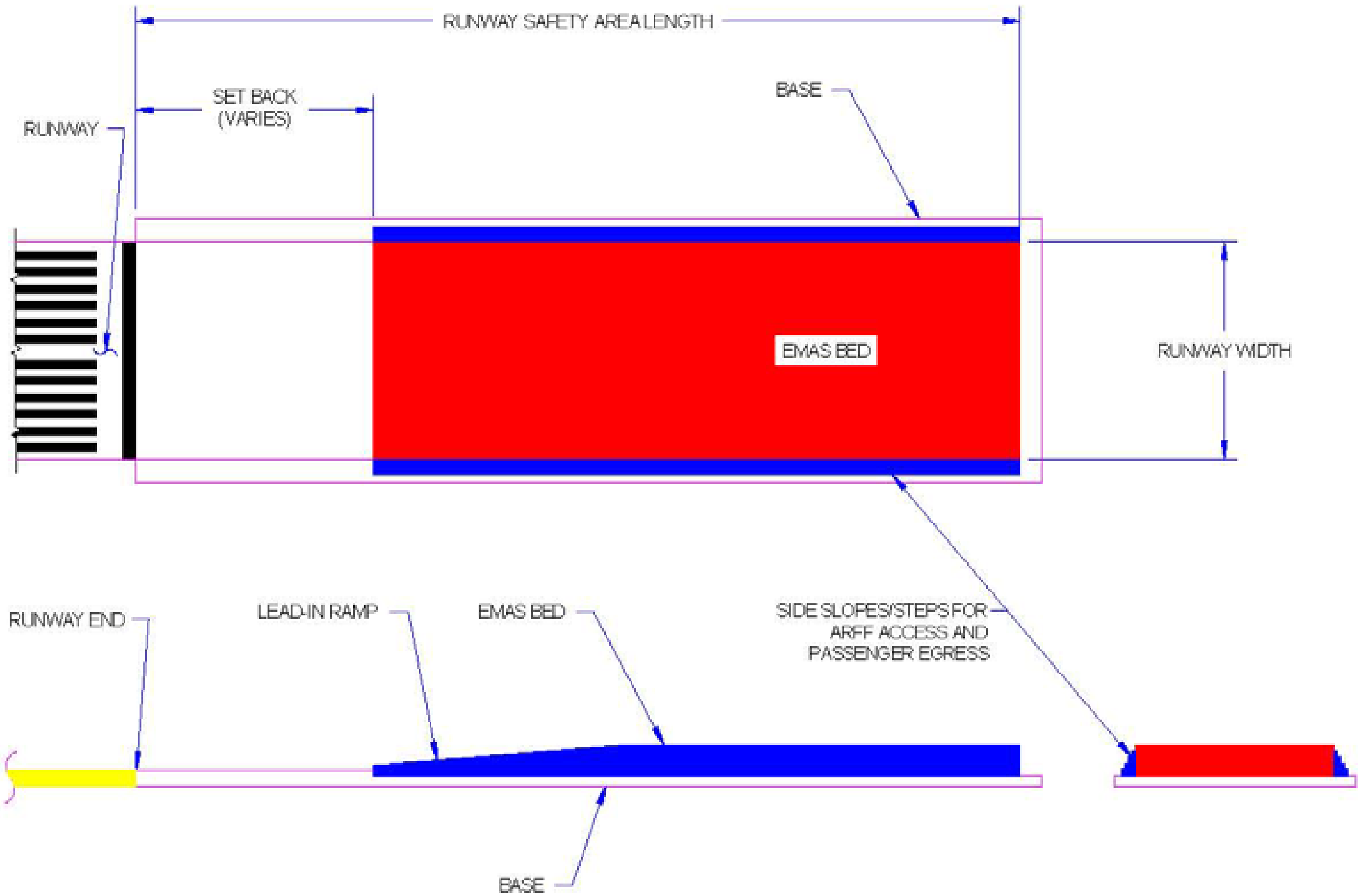


FIGURE A1-2. EMAS TYPICAL SECTION.

APPENDIX 2. PLANNING CHARTS.

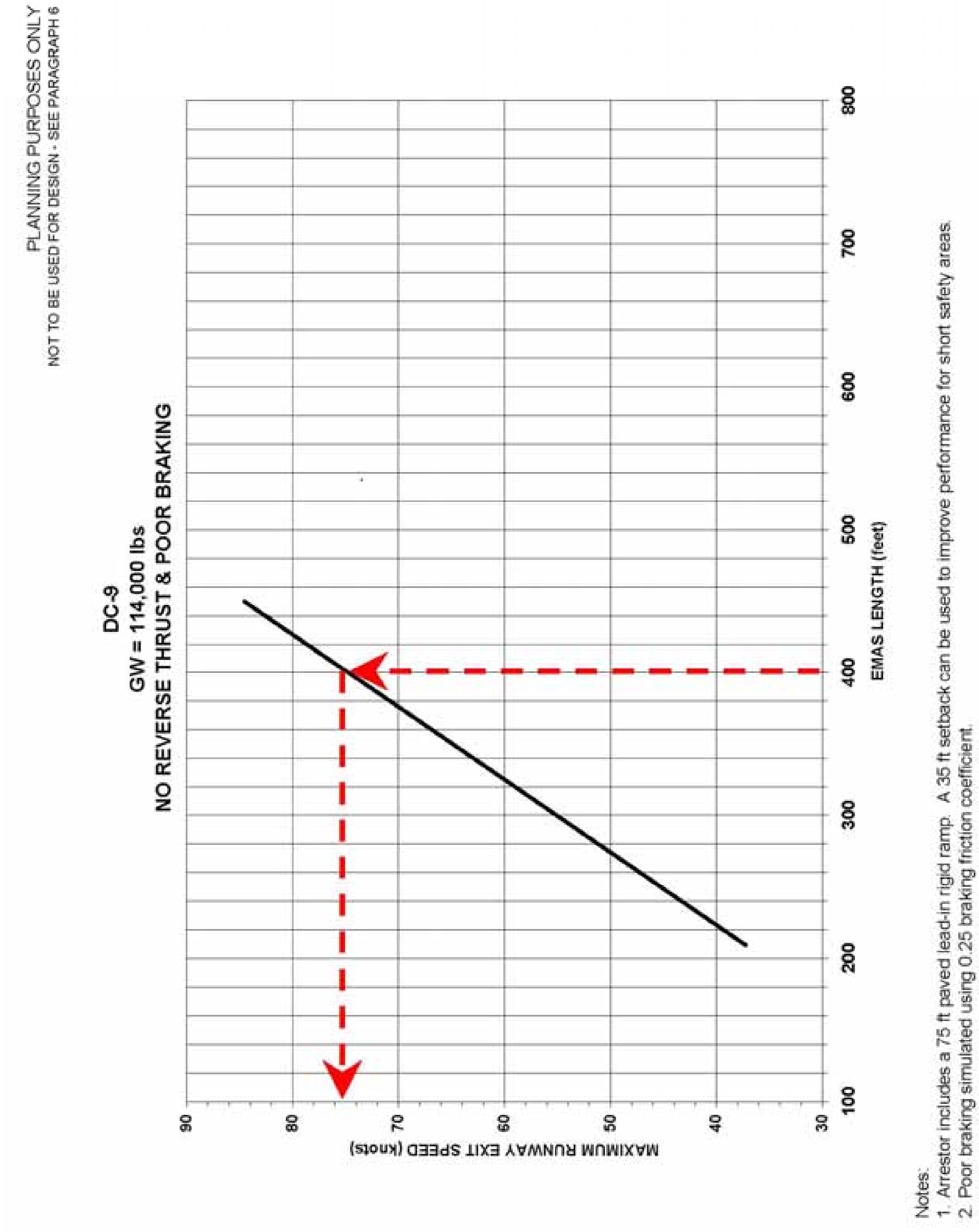
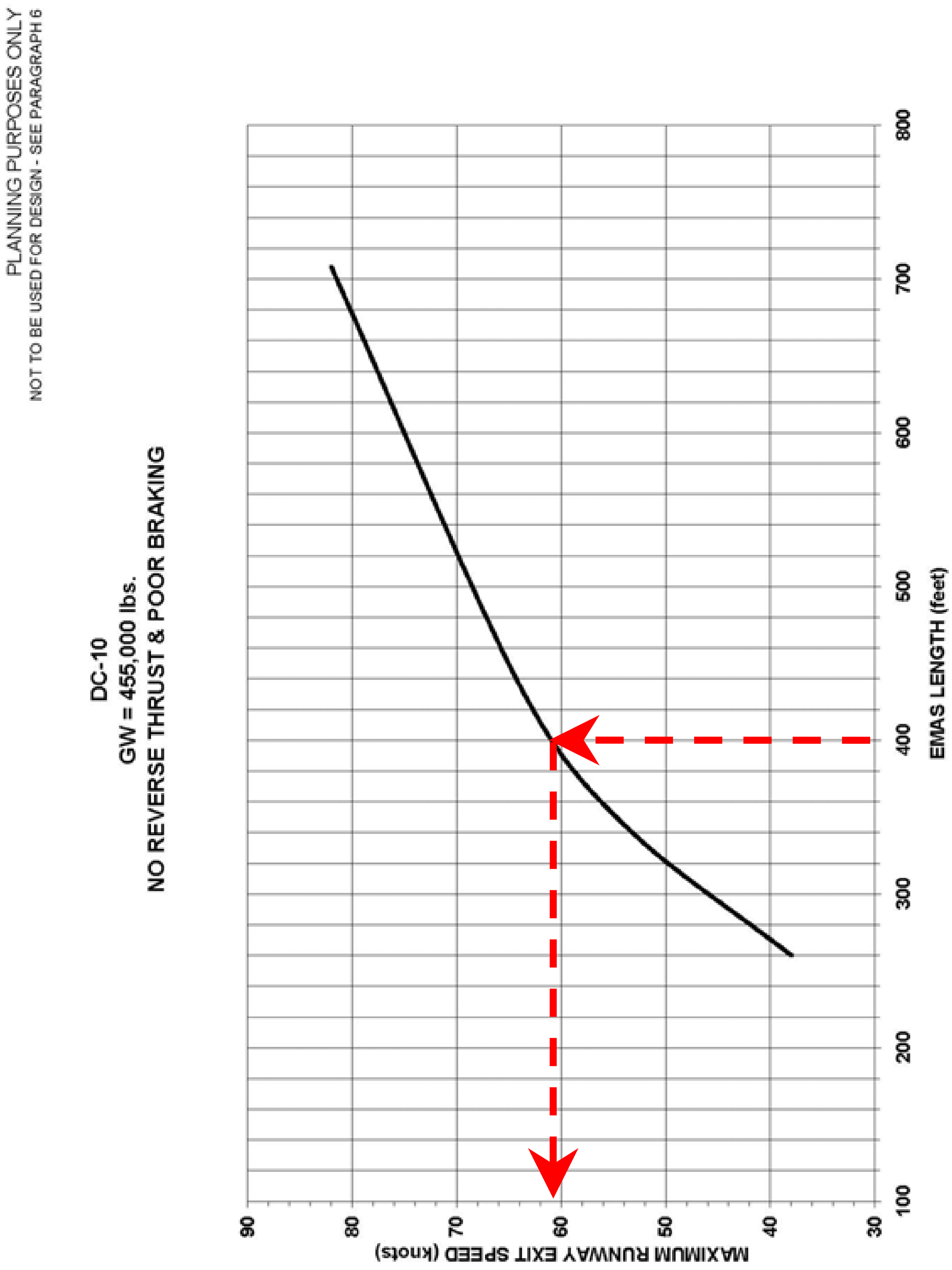
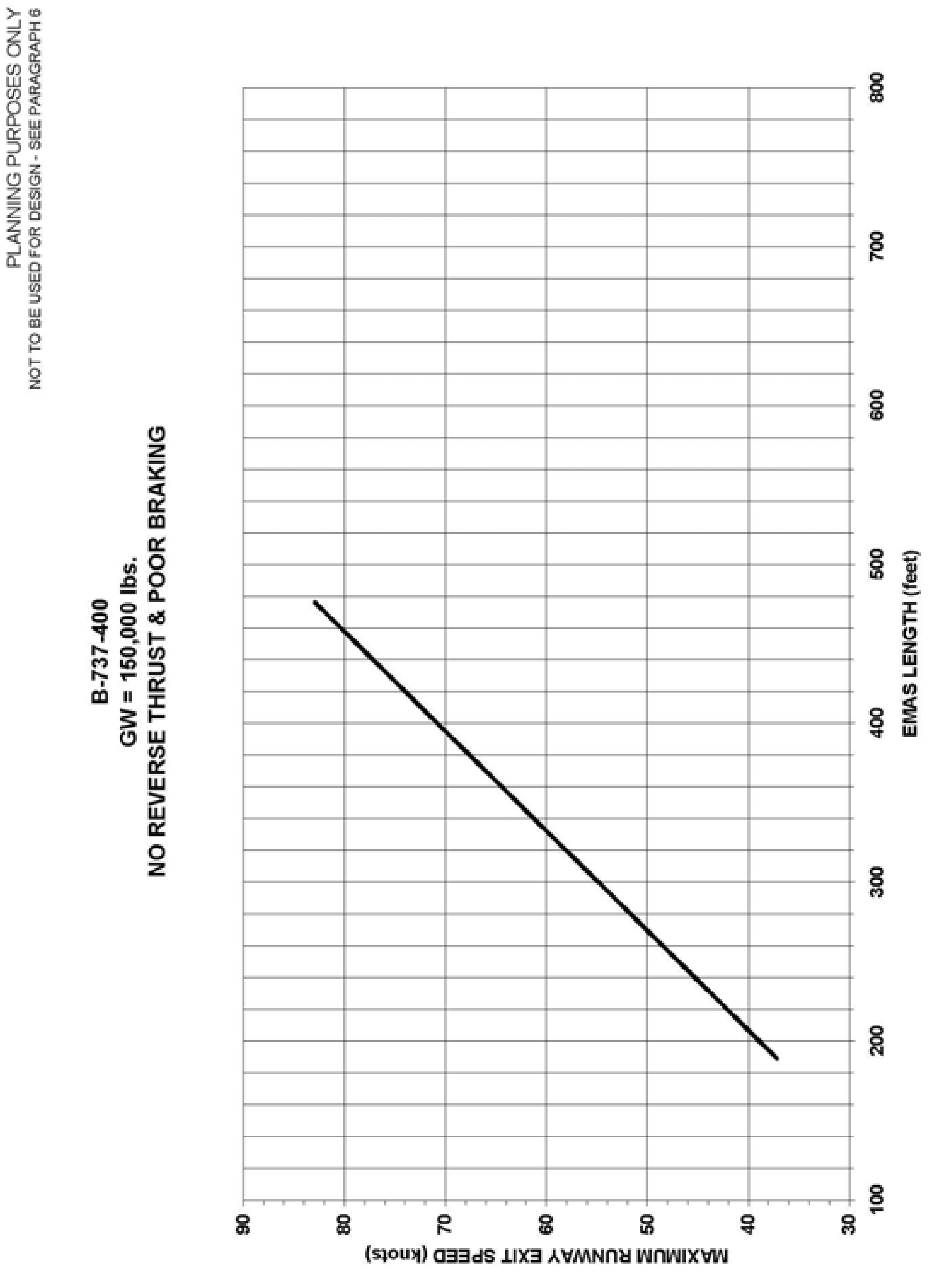


FIGURE A2-1.



Notes:
1. Arrestor includes a 75 ft paved lead-in rigid ramp. A 35 ft setback can be used to improve performance for short safety areas.
2. Poor braking simulated using 0.25 braking friction coefficient.

FIGURE A2-2.

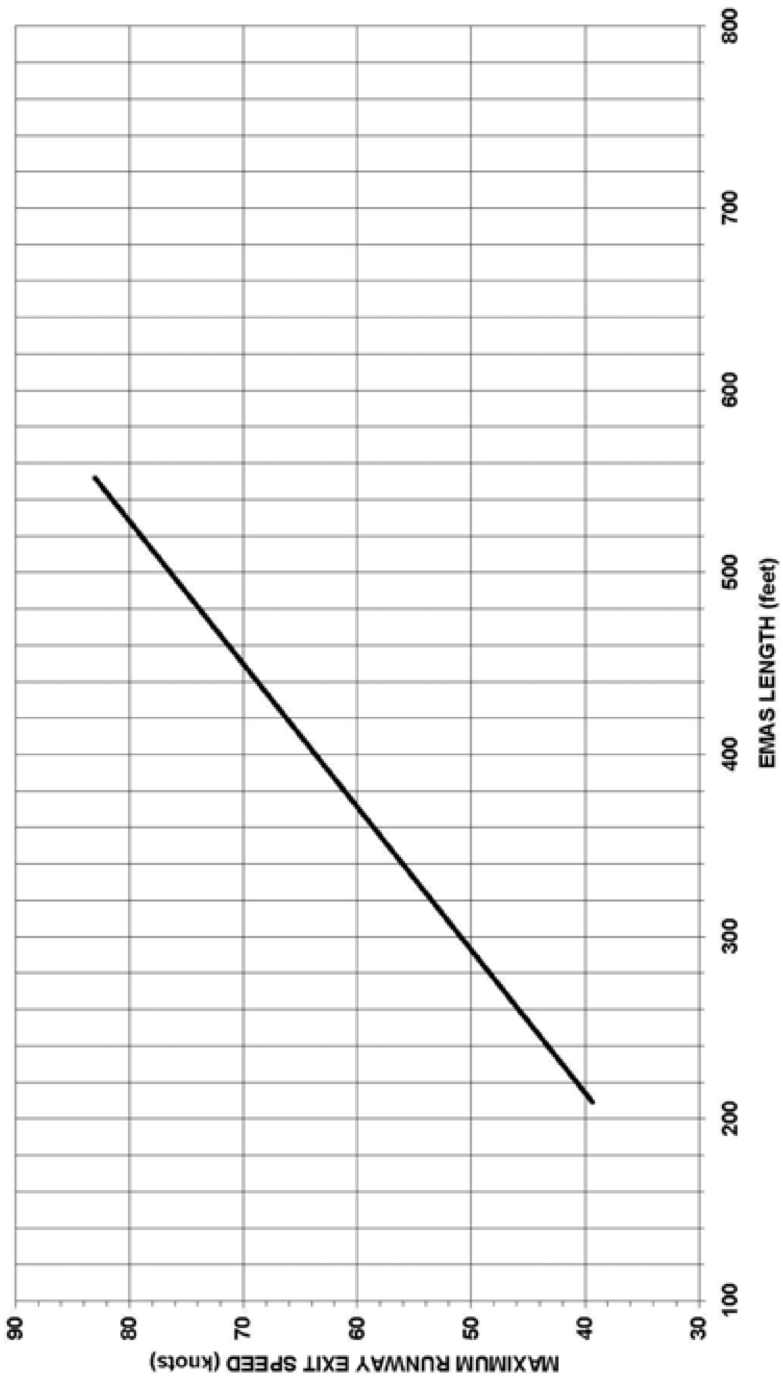


Notes:
1. Arrestor includes a 75 ft paved lead-in rigid ramp. A 35 ft setback can be used to improve performance for short safety areas.
2. Poor braking simulated using 0.25 braking friction coefficient.

FIGURE A2-3.

PLANNING PURPOSES ONLY
NOT TO BE USED FOR DESIGN - SEE PARAGRAPH 6

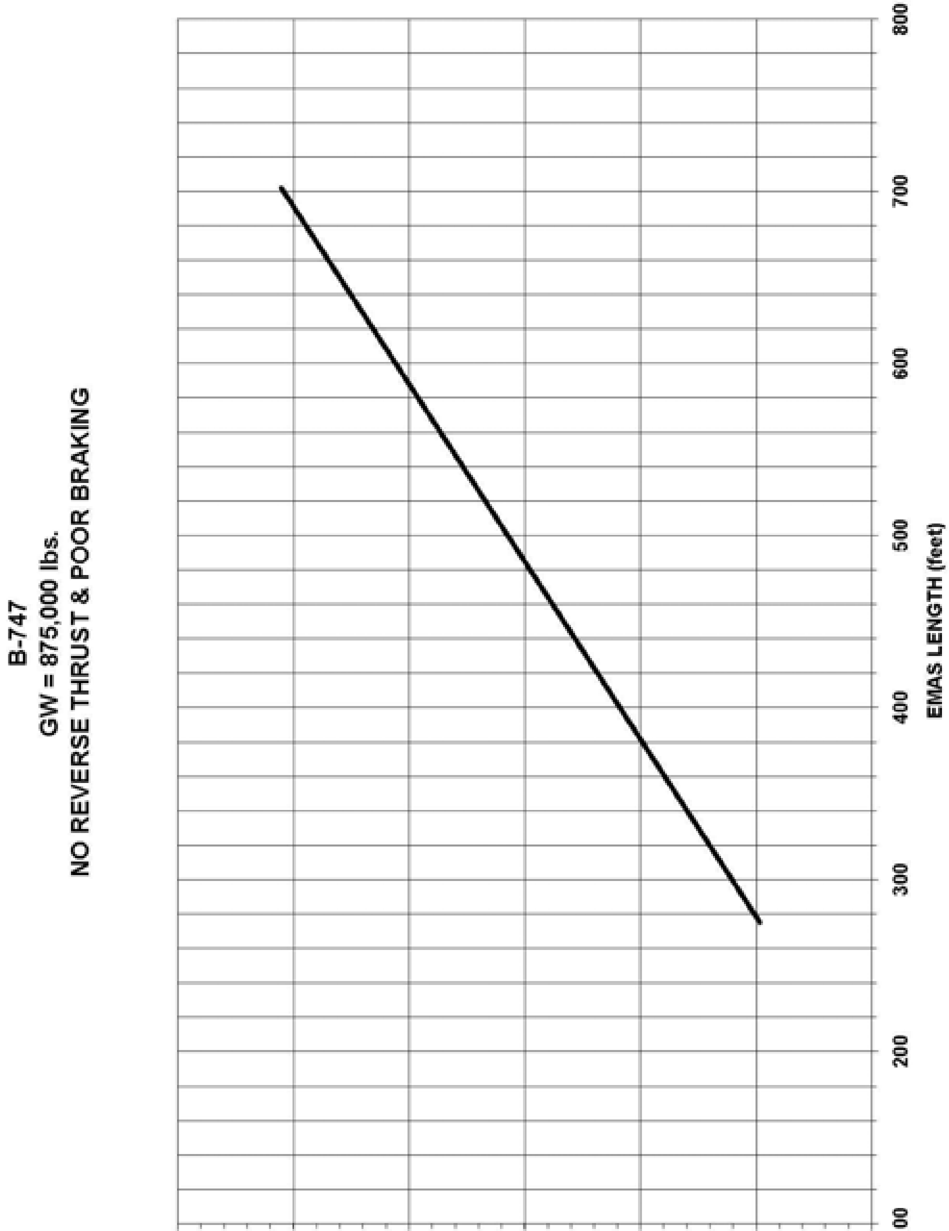
B-757
GW = 255,000 lbs.
NO REVERSE THRUST & POOR BRAKING



Notes:
1. Arrestor includes a 75 ft paved lead-in rigid ramp. A 35 ft setback can be used to improve performance for short safety areas.
2. Poor braking simulated using 0.25 braking friction coefficient.

FIGURE A2-4.

PLANNING PURPOSES ONLY
NOT TO BE USED FOR DESIGN - SEE PARAGRAPH 6

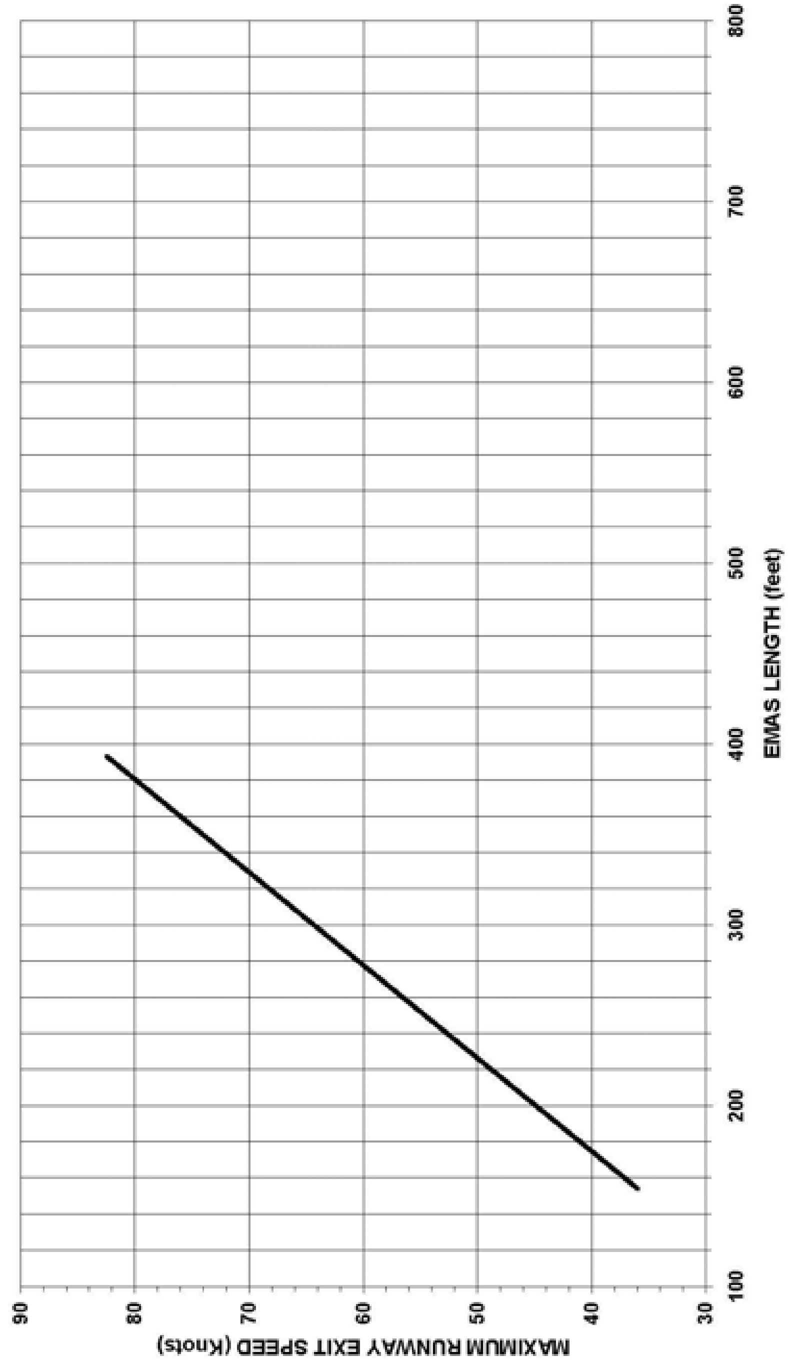


Notes:
1. Arrestor includes a 75 ft paved lead-in rigid ramp. A 35 ft setback can be used to improve performance for short safety areas.
2. Poor braking simulated using 0.25 braking friction coefficient.

FIGURE A2-5.

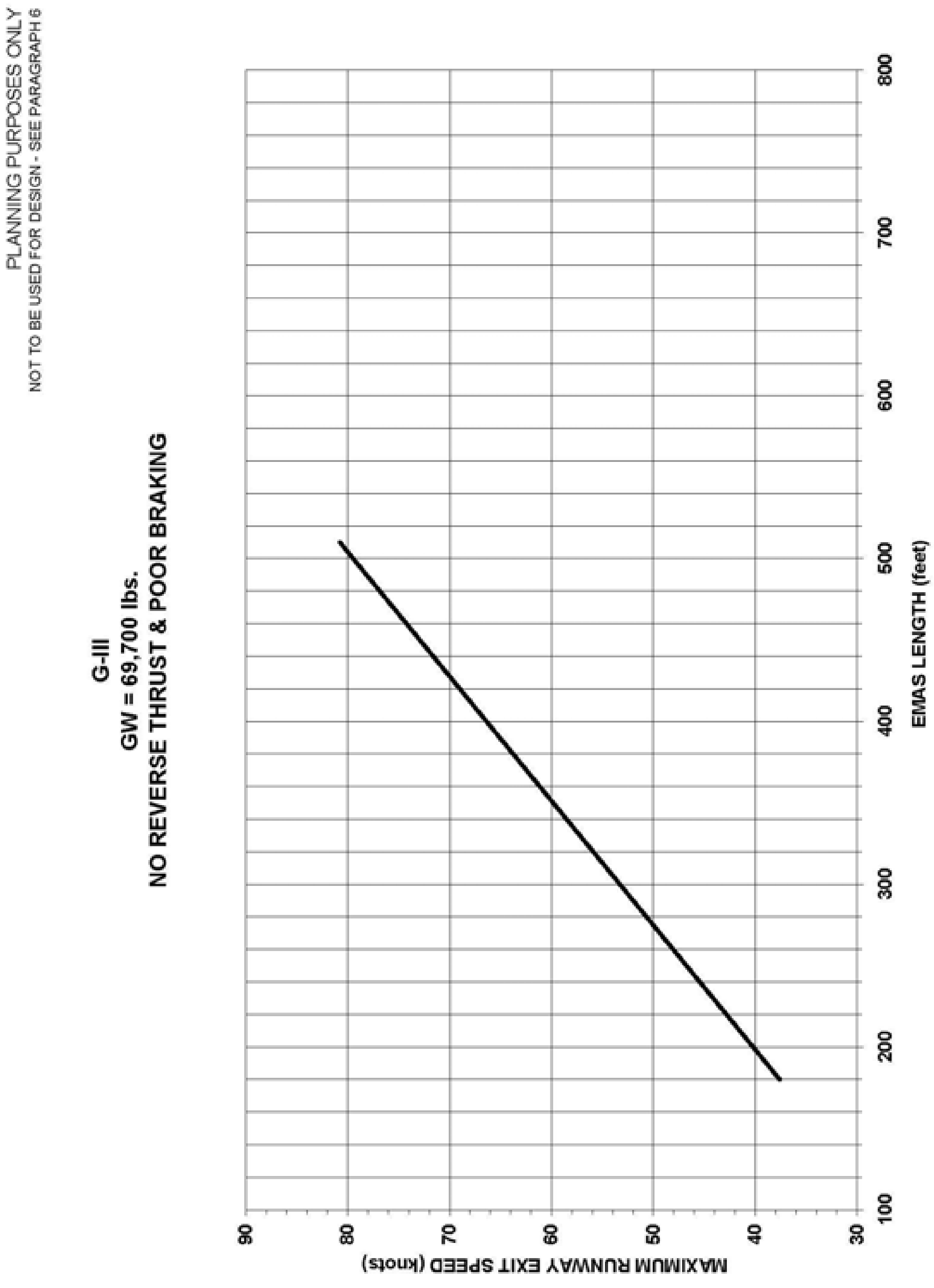
PLANNING PURPOSES ONLY
NOT TO BE USED FOR DESIGN - SEE PARAGRAPH 6

CRJ-200
GW = 53,000 lbs.
NO REVERSE THRUST & POOR BRAKING



Notes:
1. Arrestor includes a 75 ft paved lead-in rigid ramp. A 35 ft setback can be used to improve performance for short safety areas.
2. Poor braking simulated using 0.25 braking friction coefficient.

FIGURE A2-6.



Notes:
1. Arrestor includes a 75 ft paved lead-in rigid ramp. A 35 ft setback can be used to improve performance for short safety areas.
2. Poor braking simulated using 0.25 braking friction coefficient.

FIGURE A2-7.

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APPENDIX 3. INSPECTION AND MAINTENACE PROGRAM.

An inspection and maintenance program, prepared by the EMAS manufacturer, will be submitted to and approved by the FAA Regional/Airports District Office. The Airport sponsor must implement the approved inspection and maintenance program. As a minimum, a basic EMAS inspection and maintenance program must address the following areas:

1. General information on the EMAS bed including
    - A description of the EMAS bed
    - Material description
    - Contact information for the EMAS manufacturer
2. Inspection requirements including:
    - Type and frequency of required inspections
    - Training of personnel
    - Instructions on how to conduct each inspection
    - List of typical problems and possible solutions
    - Required documentation for inspections
    - Inspection forms
3. Maintenance and repair procedures including:
    - List of approved materials and tools
    - Description of repair procedures for typical damage to an EMAS bed such as repairing depressions/holes, abrasion damage, replacing a damaged block, repairing coatings, caulking/joint repair, etc.
4. Any unique requirements due to location such as snow removal requirements and methods. Identify compatible deicing agents. Specify snow removal equipment that is compatible with the EMAS bed and recommended clearing procedures and/or limitations.
5. Warranty information

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APPENDIX 4. RELATED READING MATERIAL.

This appendix contains a listing of documents with supplemental material relating to the subject of EMAS. These documents contain certain information on materials evaluated as well as design, construction, and testing procedures utilized to date. These publications may be obtained from the National Technical Information Service (NTIS), Springfield, VA 22151.

1. DOT/FAA/PM-87/27, *Soft Ground Arresting Systems*, Final Report, Sept. 1986–Aug. 1987, published Aug. 1987 by R.F. Cook, Universal Energy Systems, Inc., Dayton, OH.

2. 2. DOT/FAA/CT-93/4, *Soft Ground Arresting Systems for Commercial Aircraft*, Interim Report, Feb. 1993 by Robert Cook.

3. DOT/FAA/CT-93/80, *Soft Ground Arresting Systems for Airports*, Final Report, Dec. 1993 by Jim White, Satish K. Agrawal, and Robert Cook.

4. DOT/FAA/AOV 90-1, *Location of Commercial Aircraft Accidents/Incidents Relative to Runways*, July 1990.

5. UDR-TR-88-07, *Evaluation of a Foam Arrestor Bed for Aircraft Safety Overrun Areas*, 1988 by Cook, R.F., University of Dayton Research Institute, Dayton, OH.

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