TRANSIT

RAPID TRANSIT SYSTEM EXTENSIONS
COMPENDIUM OF DESIGN CRITERIA

VOLUME VII
SYSTEM EQUIPMENT DESIGN CRITERIA

CHAPTER 5
PASSENGER VEHICLE DESIGN CRITERIA

INTERIM RELEASE
REV 1

OCTOBER 30, 2008

PROGRAM MANAGEMENT CONSULTANT

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MIAMI-DADE COUNTY TRANSIT

VOLUME VII – SYSTEM EQUIPMENT

CHAPTER 5 – PASSENGER VEHICLE DESIGN CRITERIA

REVISION 1

Program Management Consultant

Submitted _____ Date 5/1/09
Project Manager, Soji Tinubu

Miami-Dade Transit
Engineering Review Board Members

Approval _____ Date 5/4/09
Chief of Design & Engineering, Isabel Padrón

_____ Date 5/4/09
Chief of Construction, Ron Steiner

_____ Date 5/4/09
Chief of Safety, Eric Muntan

_____ Date 5/4/09
Manager of Systems Engineering, Daniel Mondesir

Director Approval

Approval _____ Date 5/4/09
Deputy Director, Albert A. Hernandez

Approval _____ Date 06/01/09
MDT Director, Harpal Kapoor

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DOCUMENT REVISION RECORD

ISSUE NO.	DATE	REVISION DESCRIPTIONS
0	5-10-07	Interim Release
1	10-30-08	Revisions to incorporate MIC-EH design specifications that have been adopted by MDT.

ISSUE NO.	SECTIONS CHANGED
1	Table of Contents – (pagination changes)
	5.02.1.2 Passenger Vehicle Width - Reference to Vol II, Chap 2 - Aerial Guideway, Civil and Trackwork Design Criteria added.
	5.02.1.5 Passenger Vehicle Trucks - Commentary added regarding stage 1 vehicle bounce natural frequency and suspension
	5.02.2.1 Track Characteristics, Rail Type - Text added for clarification of rail type
	5.02.2.2 Track Characteristics, Lateral Curves - Commentary added "possible 350 foot radius curves in East-West"
	5.02.2.4 Track Characteristics, Most Severe Reverse Curve Conditions – minimum tangent length changed.
	5.02.2.11 Track Characteristics, Contact Rail - text added. "For Vehicle Design purpose only, the Designers can assume the following".
	5.02.3.1 Station and Guideway Characteristics, Stations - "Minimum" added to platform Length - Changed platform edge to track centerline dimension
	5.03.1.2 Performance Requirements, Standard Conditions for Specified Performance, Definition of Standard Train - Section revised; Commentary expanded
	5.07 Auxiliary Power: Correction of auxiliary power inverter voltage specification.

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VOLUME VII – SYSTEM EQUIPMENT

CHAPTER 5 – PASSENGER VEHICLE DESIGN CRITERIA

REVISION 1

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5.01 GENERAL

This Chapter defines the criteria for the design and manufacture of the passenger vehicle, including the operational parameters, structural strength, performance, material, vibration, acoustical, and environmental requirements.

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5.02 DIMENSIONS AND DESIGN CONSIDERATIONS

The vehicle must operate successfully on the track and structure described in Sections 5.02.2 and 5.02.3.

5.02.1 PASSENGER VEHICLE

Physical characteristics of the vehicle shall be as follows:

5.02.1.1 Lengths

Lengths over couplers	75 feet
Length over anticlimbers	74 feet, 8 inches
Distance, center to center of trucks	52 feet to 54 feet

5.02.1.2 Widths

Maximum width	(comply with Dynamic Envelope – See Volume III Chapter 2 – Aerial Guideway Civil & Trackwork - Directive Drawing VPD001)
Width over threshold	10 feet 3 inches

5.02.1.3 Heights

Empty car with new wheels:

Top of rail to top of roof(w/o antenna)	12 feet maximum

Top of rail to car floor (with new wheels)	3 feet, 7-1/2 inches
Top of rail to top of anticlimber	3 feet, 7½ inches
Top of rail to center line of coupler	25⅜ inches
Top of rail to bottom of under-floor equipment under worst, condition worn wheels, deflated air springs and AW3 load	6 inches min.
Top of rail to bottom of truck-mounted equipment under worst condition with worn wheels, deflated air springs and AW3 load	3 inches min.
Minimum height, floor to headlining at centerline of car	6 feet, 8 inches

5.02.1.4 Doors

Doors per side	3 each
Width of side door openings	48½ inches
Width of end door openings	30 inches

Height of side door openings	6 feet 7 inches
Height of end door opening	6 feet 7 inches

5.02.1.5 Trucks

Truck wheel base	6 feet, 10 inches to 8 feet, 6 inches
Wheel diameter, new	28 inches
Maximum wheel wear on diameter	2.5 inches
Wheel gauge (Nominal)	4 feet, 7-11/16 inches

Commentary: *From information received from Bombardier, it is believed that the Stage I Rail Cars were designed with a Bounce Natural Frequency of 1.26 Hz at Crush Load, and a secondary suspension stiffness per car of 15,144 lb/in.*

5.02.2 TRACK CHARACTERISTICS

The following data are given to assist the Contractor with the design of the vehicle. If any of these are critical to the design, the Contractor is advised to request the Engineer to reconfirm the specific data at the time of design.

5.02.2.1 Rail Type

For vehicle design purposes only, the designer can assume 115 RE section, continuously welded, having a 1:40 cant, and a resistance equal to 9.04 micro ohms/ft.

5.02.2.2 Lateral Curves

Minimum lateral radius at centerline of tracks outside of special track work

Yard	250 feet
Mainline	1,000 feet

Commentary: *Future mainline curve for the East-West Corridor Extension may involve a 350 feet Radius curve.*

5.02.2.3 Superelevation

Maximum Superelevation: Ea = 4.5 inches

Maximum Unbalanced Superelevation: E_U = 4.5 inches

5.02.2.4 Most Severe Reverse Curve Conditions

Outside of special trackwork: The absolute minimum tangent length shall be 100 feet (refer to Volume III – Aerial Guideway, Chapter 2 – Civil & Trackwork) .

Yard special work: Crossover consisting of two No. 6 turnouts, 13 foot curve switches, crossing between parallel tracks 14 feet apart.

5.02.2.5 Smallest Turnout

No. 6

5.02.2.6 Vertical Grades and Curves

Refer to Volume III Aerial Guideway, Chapter 2 Civil & Trackwork, Section 2.4 – Vertical Alignment.

5.02.2.7 Nominal Track Gauge

A. Standard trackwork:

Tangent track	4 feet, 8-1/4 inches Mainline
Curve radius greater than 1,500 feet	4 feet, 8-1/2 inches Mainline
Curve radius between 1,500 and 1,000 feet	4 feet, 8-3/4 inches
Curve radius less than 1,000 feet	4 feet, 9 inches

B. Special Trackwork

Turnout No.	Straight Side	Turnout Side
8,10, & 15	4 feet, 8-1/2 inches	4 feet, 8-1/2 inches
6	4 feet, 8-I/2 inches	4 feet, 9 inches

1. If guard rails are used, Guard Rail Gauge will be 4 feet, 6-5/8 inches regardless of track gauge.

2. Self-guarded frogs will be used in yard.

Double crossover gauge will be 4 feet, 8-1/2 inches between the frogs.

For every 1/4 inch change in track gauge, the transition length shall be not less than 31 feet except in special trackwork.

5.02.2.8 Track Quality

Minimum track quality shall be FRA Class 4. For ride quality purposes, track quality will be as follows:

Gauge variation, per 31 feet of track	± 1/4 inch
Cross level variation, per 31 feet of track	± 1/4 inch
Superelevation, per 31 feet of track	± 1/4 inch
Vertical and horizontal alignment, mid ordinate, 62 feet chord	± 1/4 inch
Contact rail elevation	± 1/4 inch

5.02.2.9 Track Spacing

Fourteen feet minimum, center to center, tangent track.

5.02.2.10 Running Rail Wear

Maximum of 0.50 inches vertical and horizontal.

5.02.2.11 Contact Rail

For Vehicle Design Purpose only, the Designers can assume the following:

Mainline: 85 pound ASCE composite, 2.0 micro ohms/foot

Yard: 85 pound ASCE, 11.7 micro ohms/foot

Nominal height of top of contact rail above top of running rail: 4.5 inches

Nominal contact rail ramp:

High speed: 1.6 degrees nominal

Slow speed: 3.0 degrees nominal

Distance between centerline of contact rail and gauge point of near running rail: 2 feet, 2 inches

5.02.3 STATION AND GUIDEWAY CHARACTERISTICS

5.02.3.1 Stations

Minimum Platform Length	456 feet
Platform Height - above top of rail	43 inches
Platform Edge from centerline of track	64.25 inches

5.02.4 WEIGHT CRITERIA

The maximum allowable empty A-car or B-car weight shall be 80,000 pounds including all MDT furnished equipment. The maximum permitted weight difference between an A-car and a B-car shall be not greater than 1,500 pounds with all MDT furnished equipment installed. The weight measured under each truck shall not be less than 54/46 percent of the actual total weight.

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5.03 PERFORMANCE REQUIREMENTS

5.03.1 STANDARD CONDITIONS FOR SPECIFIED PERFORMANCE

5.03.1.1 Primary Electrical Power

Nominal system voltage will be 750 volt DC at the vehicle contact rail interface. All vehicle system performance requirements shall be met with any voltage between 600 volt DC and 900 volt DC. All equipment must be able to function properly, but not necessarily to specified performance, with voltages between 450 volt DC and 599 volt DC.

5.03.1.2 Definition of Standard Train

A train consist may contain two, four, six, or eight rail cars (one, two, three or four married pairs). For performance verification testing, the standard train shall be the two cars comprising a single married pair.

For performance purposes, the weight of each car shall be defined by the following table:

Symbol	Condition	Weight
AWO	Empty Weight Ready to Run	80,000 pounds (maximum allowed with county equipment)
AW1	Empty Weight Plus Seated Load	AWO + 150 lbs/Seated Passenger plus train operator
AW2	Empty Weight Plus Seated plus Standing Load	AWO + 150 lbs/Seated Passenger plus train operator plus standees using a standee space is 2.5 ft²/passenger
AW3	Crush Load Maximum Guideway Design Load (MGDL)	AWO + 150 lbs/Seated Passenger plus train operator plus standees using a standee space of 2.0 ft²/passenger Shall not exceed 120,000 lbs

*For Stage 1 the AW3 was determined using 275 passengers and AW3 was used for vehicle design purposes only.

Commentary: *The Maximum Guideway Design Load (MGDL) for the guideway design for Stage 1 was defined as AW0 (78,000 lbs.) plus 250 passengers of 150 pounds each, or a maximum of 115,500 pounds. The standing passenger density for the MGDL based upon the Stage 1 rail car was determined to be 280 square inches (1.94 square feet) per passenger. The area for standing passengers shall include the full width and length of aisles and all open and usable areas to the front face of bench seats and exit/entrance doors. For new rail car procurements, the 1.94 square foot value was rounded to 2.0 square feet and an analysis of the remaining life of the Stage 1 guideway indicates that the MGDL can be increased to 120,000 lbs which results in an acceptable reduction in overall Stage 1 guideway fatigue life. When calculating the MGDL, the space of the cab area is not included as space for standees but the weight of the train operator needs to be included. All spaces for bicycles and wheel chair use shall be loaded with standing passengers. Where seats face an aisle a maximum of 8 inches can be deducted from the aisle space and determining the usable space for standees to allow for the aisle space occupied by the seated passenger's legs. Any gangway space between rail cars not intended for use by standing passengers can be ignored.*.

5.03.1.3 Condition of Standard Car

The specified acceleration, deceleration and running speed shall be met with new and worn wheels.

5.03.2 STANDARD TRAIN PERFORMANCE TABLE

The following table summarizes the standard train performance on level tangent track. Succeeding paragraphs detail the performance requirements.

Maximum Speed	70 mph
Maximum Initial Acceleration	3.0 mphps
Maximum Service Braking (nominal)	-3.0 mphps
A. Blend Service Braking (70 mph to 50 mph)	-2.25 to -3.0 mphps
B. Blended Service Braking (50 mph to 5 mph)	-3.0 mphps
C. Friction Only Service Braking	-3.0 mphps
D. Emergency Braking	-3.2 mphps
E. Jerk Rate	2.0 mphpsps
Distance traveled from a standing start in 20 seconds on level tangent track @ AW2 weight	700 feet
Slip-Spin Efficiency	90%

5.03.3 DUTY CYCLE AND ENERGY CONSUMPTION REQUIREMENTS

5.03.3.1 The thermal capacity design of the propulsion and friction brake systems shall be based on a duty cycle of a standard train operating between terminal points of the Stage I route. Station dwell times will be 20 seconds; turn back times at the terminals will be 45 seconds. The route shall be run from terminal to terminal (including station dwell times) in 4400 seconds for propulsion only.

Car weight shall be AW2. Propulsion system design shall be based on continuous operation. Friction brake system thermal design shall be based on the round trip of this duty cycle with the electric braking inoperative and with a run time of 4,600 seconds.

5.03.4 ACCELERATION REQUIREMENTS

The acceleration performance of the standard train shall be based on a car weight of AW2.

Maximum Initial Acceleration	3.0 mphps

Deviation from the maximum initial acceleration, between zero mph and base speed, shall not exceed plus or minus 10 percent of maximum initial acceleration. This shall be under control of the load weighing system and does not apply to periods where limited by jerk rate control.

The standard train shall be capable of traveling 700 feet within 20 seconds from a standing start on level tangent track. The time will commence upon initiation of the control signal by the train operator.

5.03.5 CONTINUOUS SPEED REQUIREMENTS

5.03.5.1 The standard train, AW2 weight, shall be capable of maintaining a continuous speed of 70 mph on a 1.0 percent adverse grade.

5.03.5.2 When operating in the Manual Train Operation/Wash mode, the train speed shall be regulated to two mph or less by the propulsion control equipment.

5.03.6 DECELERATION REQUIREMENTS

5.03.6.1 Service braking shall be a blending of electrical brakes and friction brakes. Below the assigned weight AW2, the electrical brake shall provide all braking effort down to a speed of five mph.

5.03.6.2 The following blended service brake rates shall be available for a standard train with passenger loads up to and including AW2:

Speed	Braking Rate
70 mph	2.25 mphps
70 - 50 mph	linear increase from 2.25 to 3.0 mphps
50 - 0 mph	3.0 mphps

The above rates and any lower blended rates requested by the tractive effort control shall be maintained within plus or minus seven percent in any five second interval above five mph. Peak blended rates shall not deviate beyond plus or minus 10 percent of that requested for all speeds above five mph.

5.03.6.3 With electrical brakes cut out, the service friction brakes alone shall be capable of providing braking rates as defined in Section 5.03.6.2. Friction only average rates shall be measured by using a time period beginning at the completion of jerk limiting and ending at zero mph.

The average rate achieved shall be within ± 20 percent of the requested rate. Peak rates shall not deviate plus or minus 30 percent of the requested rate.

5.03.6.4 Under emergency braking, the braking rate for a standard train shall not be less than 3.2 mphps exclusive of dead time and brake build up time. Total dead time and brake build up time (to 90 percent of final brake cylinder pressure) shall not exceed one and one-half seconds. Jerk limiting shall not be active during emergency braking. Instantaneous maximum brake rate shall not exceed 4.5 mphps.

5.03.7 WHEEL SPIN/SLIDE PROTECTION

The wheel spin/slide protection system shall detect slips whether random or synchronous and shall operate in both braking and propulsion modes. In the braking mode, fail safety shall be inherent in the design so that a failure of the spin/slide system will result in no less than the commanded brake cylinder pressure. The efficiency of the spin/slide system in the braking mode above eight percent adhesion and 5 mph shall be at least 80 percent.

5.03.8 JERK RATE

The rate of change of acceleration or deceleration shall be 2.0 mphpsps plus 1.0 mphpsps minus zero mphpsps. Jerk limiting shall not apply to emergency braking. Jerk rate shall remain within the above limits during the time period beginning at the initial change in tractive effort until 90 percent of commanded acceleration/deceleration rate has been achieved.

5.03.9 CONTROL RESPONSE (DEAD) TIME

Dead time from a step change of command signal until the beginning of traction system torque reaction shall be:

Mode Change (Drive to Brake or Brake to Drive)	0.3 sec
Modulation within the Drive or Brake Modes	0.1 sec

5.03.10 LOAD WEIGH SYSTEM

The load weighing compensation signals to the propulsion and braking system shall be a continuous function available for all transit car weights up to and including AW3. The load weighing system shall be designed to ensure that, if load sensing is lost, the braking system will respond as if the car weight were AWO. The load weighing system shall be damped to prevent responding to dynamic suspension motions.

5.03.11 BRAKE AND PROPULSION CONTROL SIGNALS

Tractive effort will be controlled by an analog signal that represents the percent of maximum tractive effort to be developed by propulsion and/or brake systems. Braking and propulsion shall use separate ranges of the analog signal. A separate two level signal (high/low) shall control mode changes between braking and propulsion. Another two level (high/low) signal shall control emergency braking. Propulsion and Friction Brake systems shall respond to changes greater than four percent in the analog signal.

5.03.12 PERFORMANCE DATA

Curves containing verified values of car performance shall be provided by the supplier to substantiate the performance characteristics of the vehicle. These performance data shall include all pertinent data and criteria used to derive the performance characteristics of Section 5.03 and shall include technical and actual test results.

5.03.13 TRAIN RESISTANCE

For design purposes, the train resistance of the vehicle(s) shall be calculated based on the following modified Davis equation.

$TR = 1.3W + 29n + .045WV + [(.0024) + (N-l)\ (.00034)]\ AV^2$ where:

TR = Train Resistance, total, lbs.

W = Weight per train, tons

n = Number of axles per train

V = Train speed, mph

N = Number of cars in train

A = Frontal Area of lead car, square feet

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5.04 STRENGTH REQUIREMENTS

The transit car shall be capable of resisting, without permanent deformation or failure, the loads inherent in the type of service for which it is intended. The Vehicle Contractor shall be responsible for the allowable stresses used throughout the design.

The car structure, including door support structure, shall not deform in a manner that would impair system function under normal static and dynamic loads and operating conditions.

The weight to be used for car structural analysis and design shall be the AW3 assigned weight.

Critical parts of the transit car subject to possible fatigue shall be specifically designed for the repeated loads, specific service life and environment for which the transit car is intended.

The Vehicle Contractor shall submit a complete stress analysis of the car structure, trucks and major equipment supports to show compliance with the strength requirements specified herein.

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5.05 CAR BODY

5.05.1 CAR BODY MATERIAL

The car body, including shell, frames and sills, shall be of material(s) selected to: provide corrosion protection commensurate with the marine environment of the Southern Florida region; provide the necessary structural strength and levels of safety in the event of crash, collision and fire; provide durability and robustness over the lifetime of the vehicle structure; and support achievement of the vehicle weight limitations. Protective coatings shall be applied as necessary to inhibit corrosion. Techniques of joining dissimilar materials will be consistent with the prevention of corrosion across adjoining surfaces.

5.05.2 INTERIORS

Vehicle interiors shall be made of materials that resist vandalism and graffiti, and that facilitate cleaning. Important attributes for consideration of interior materials include safety, durability and appearance.

5.05.3 STRUCTURAL SAFETY

The car body shall be designed to maximize the energy-absorbing capability of the car body structure and to minimize injuries to passengers in the event of end collisions. The car body structure shall be designed to crush in a controlled manner during end impacts where the forces generated exceed the elastic capability of the structure. Crushing shall commence at the ends of the structure and progress inward with no failure of vehicle body occurring in the zone between the vehicles bolster structures over the passenger compartment, during end crush. During a crash, all of the end structural members shall retain their attachments to one another and to the roof and floor structures. The amount of energy absorbed during controlled crushing of the car end structure shall be the maximum possible within the car body and interior arrangement. In no case shall the amount of energy absorbed by

the end structure during controlled crush of the vehicle be less than 950,000 foot pounds. The end force that will result in such energy absorption shall not exceed 800,000 pounds. A computer crash worthiness analysis shall be performed to simulate a single vehicle impacting a barrier. Structural design for crash worthiness shall also include, but not limited to, the following:

A. End under frame members shall crush at a designed controlled rate and provide energy absorption required for keeping the integrity of each from disintegration and this capability shall be proven through approved testing.

B. The portions of the vehicle body designed for controlled crushing and energy absorption shall not include train line boxes, couplers, attachments, equipment groups and other members not designed for controlled crushing.

C. A crash worthiness analysis shall be performed and must demonstrate:
   1. Quantity of energy absorbed by non-crush members in crush zone.
   2. Energy absorption levels of intended non–energy absorbing members.
   3. No interference of intended non-energy absorbing equipment and members, with energy absorbing members.
   4. No failures of vehicle body at the zone within the vehicle bolster structures during end crush.

The new vehicles must also be structurally compatible with the MDT's existing vehicles.

5.06 PROPULSION SYSTEM

The vehicles shall be propelled by AC Propulsion equipment.

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5.07 AUXILIARY POWER

Power required for vehicle auxiliary systems shall be provided from a three phase, fixed frequency DC/AC auxiliary power inverter supply other than propulsion power. The power inverter output shall be 120/208 or 120/230 VAC, 60 Hz, three phase from 750 VDC power input and shall utilize state of the art DC/AC power conversion techniques. These devices shall be designed to maximize efficiency, reliability and maintainability. Auxiliary power shall also include a 37.5 VDC filtered, regulated control voltage supply which shall convert input voltage of 750 VDC or 120/208 VAC to low voltage for supplying power to all vehicle low voltage controls and door operators

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5.08 VEHICLE DIAGNOSTICS – Vehicle Monitor Control System (VMCS)

The Vehicle Monitoring & Control System (VMCS) is a vehicle on-board subsystem which provides vehicle fault and status monitoring with provisions for controlling functions onboard the vehicles (for example, door control). The VMCS shall interface with on-board subsystem fault monitoring systems to allow specified faults and conditions to be transmitted to MDT Central Control and Lehman Center for monitoring and action.

The operation, fault status, fault data logging, incident investigation, and reporting of onboard systems is controlled as an integrated system of distributed intelligence. Remote monitoring is accomplished by interfacing the onboard communication system and the existing MDT Ethernet or wireless network. The VMCS will report all vehicle operation and maintenance related incidents to the Lehman Center Maintenance Facility, with selected indications to be annunciated to Central Control.

The major onboard systems and devices shall include but shall not be limited to:

- Propulsion
- Friction brake
- HVAC
- Low Voltage AC and/or DC Power Supply (LVPS)
- Traction power supply
- Door Control
- ATC (ATP, ATO and TWC)
- Train radio
- Ethernet and Wireless interfacing equipment

- Communication Control Unit and Vehicle Media controller
- Public address and Intercom Systems
- Passenger Information System
- CCTV/Security System

Additionally, the VMCS shall be designed to perform the following:

- Built-in daily pre-departure test feature.
- Built-in Portable Test Unit (PTU) control for a Laptop PC or PDA devices. Database development including built-in fault trees and associated “what-if” structured menu-driven debugging steps for each subsystems.
- Interface with all onboard subsystem sensing equipment to perform the intended functions.

Data retrieval, recording, and processing from the onboard equipment transmit to specified MDT Facilities and interface with MDT’s existing network and IT installation.

5.09 VEHICLE SAFETY

The vehicle design will incorporate features to enhance the safety of passengers and crew. Areas of concern include safety in the event of fire and explosion, electrical hazards, loose or unrestrained objects or components in motion, collisions with other rail vehicles, and hazards resulting from high pressures, sharp objects and physical impact and squeezing. Passenger door controls shall be electrically interlocked in a fail safe manner, using vital components, with no-motion circuitry such that the doors can be powered open only when the train is stopped (an emergency bypass capability to this feature may be provided for use by trained personnel).

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5.10 ELECTROMAGNETIC COMPATIBILITY

The following table represents the operating frequencies for track circuits and radio operations. Any installation of new systems or equipment shall include a design analysis of the new equipment or system to assure compatibility with the in-place MDT systems.

Operating Frequencies: Track circuits shall operate at the Power Frequency (PF) of 60 Hz.

Radio Frequencies: MDT currently uses the following frequencies:

Channel/Display	Freq Tx	Freq Rx
Data	473.61250 MHz	470.61250 MHz
Operations	473.66250 MHz	470.66250 MHz
Support	473.73750 MHz	470.73750 MHz
Yard	473.68750 MHz	470.68750 MHz
Emergency Yard	473.68750 MHz	473.68750 MHz
Emergency Operations	473.66250 MHz	473.66250 MHz
Emergency Support	473.73750 MHz	473.73750 MHz

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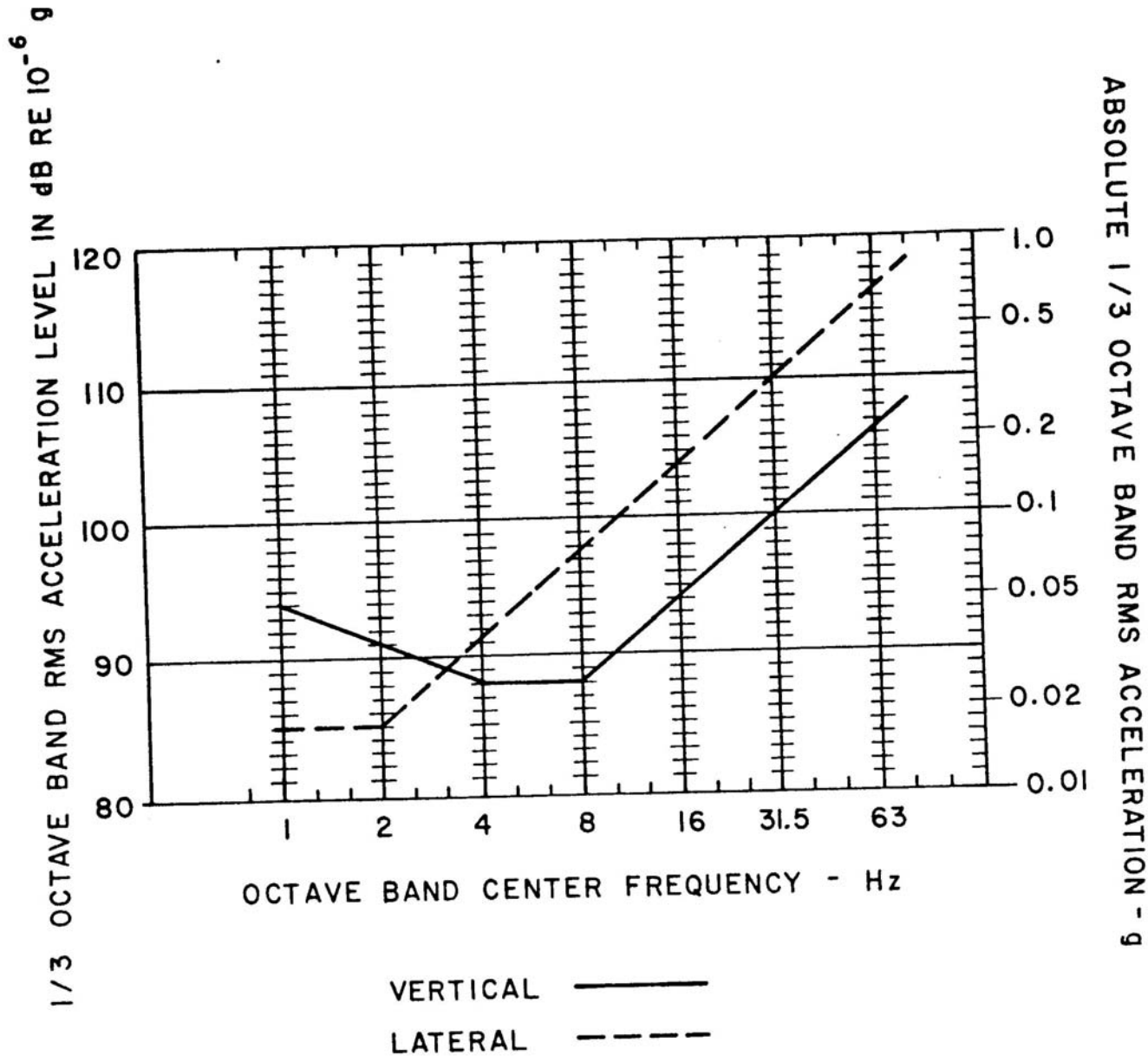

$L(\text{dB re } 10^{-6}g) = 20 \log_{10} a + 120$, where a is the acceleration in g units

FIGURE 5-1 – RIDE QUALITY LIMITS

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