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Federal Railroad Administration

Office of Research and Development

Low-Profile, Light-Weight Intermodal Railcar

Volume I: Performance Specification

FRA/ORD-81/04.I
Volume I

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R.L. Hull
S.E. Shladover

NOTICE

NOTICE

Technical Report Documentation Page

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See Volume II: Acceptance Test Plan, FRA/ORD-81/04.II and Volume III: Requirements Definition, FRA/ORD-81/04.III

16. Abstract

The Performance Specification and Acceptance Test Plan, respectively contained in Volumes I and II of this report, define the requirements for a low-profile, light-weight intermodal railcar. The Car specified here must be able to operate within restricted clearances when carrying either highway trailers or standard shipping containers and must be designed for low aerodynamic resistance and light weight in order to conserve energy. Also, it must be capable of dynamically stable operation at the high speeds which may be expected in special intermodal unit trains. Both safety and protection of lading against the damage which can be caused by excessive ride vibration must be considered in the design of the Car. It is intended that these requirements will stimulate the development of innovative railcar designs.

The Car specified here is an idealized concept which satisfies the most stringent technological requirements presently envisioned for intermodal service. The performance baseline defined here may not be equally appropriate for all users of the Specification, some of whom may wish to modify some of the requirements better to reflect their particular needs.

The Acceptance Test Plan includes not only the performance tests which must be performed to verify compliance with the Specification, but also the sequence of preliminary and detailed analyses which should be performed to facilitate development of a Car design which will meet the performance requirements.

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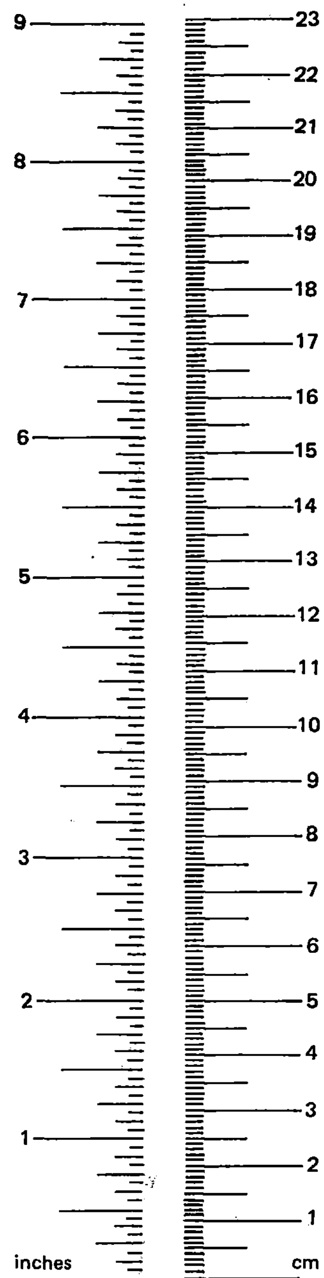
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

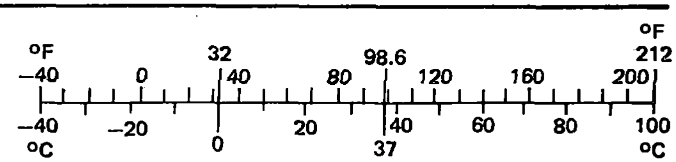
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in. = 2.54 cm (exactly). For other exact conversions and more detail tables see NBS Misc. Publ. 286. Units of Weight and Measures. Price $2.25 SD Catalog No. C13 10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The original reason for the development of the Low-Profile, Lightweight, Intermodal Railcar Performance Specification (Volume I) was for use by the Federal Railroad Administration in a planned procurement of an experimental intermodal car capable of demonstration service throughout the restricted clearances found on the Northeast railroads. Subsequently, it was decided not to proceed with the procurement, but instead, to revise the performance specification to reflect railcar requirements more attainable in the near-term and separately publish the Acceptance Test Plan (Volume II).

In light of the high level of interest in a new generation of intermodal railcars, it is believed that this work will provide a baseline to be utilized by railroads and car builders seeking new high-efficiency, all-purpose, intermodal rolling stock.

Measurement of the clearances in the North and East River Tubes and Penn Station, New York City, was performed in July 1980. Amtrak interpretation of the resulting data has indicated that intermodal railcar operations through these tubes with the most severe (clearance-wise) lading configurations of 13'6"-high trailers is not possible. Nevertheless, many of the requirements of this Specification point out the directions in which new car designs should seek to move for benefits in dynamic stability and energy efficiency. It is for this reason that the Specification and Acceptance Test Plan are being made available for use as appropriate by the railroad industry. As indicated in the Specification, the ultimate users of these documents may wish to exercise trade-off judgements on the actual application of the provisions of either the Specification or the Acceptance Test Plan or both.

Preliminary work in developing the Specification was accomplished by A.T. Kearney, Inc. and the General Motors Transportation Systems Center in the form of a Requirements Definition (Volume III). The Specification and Acceptance Test Plan, which were completed by Systems Control, Inc. (Vt), now incorporate additional information and improvements to the original work. In addition, results of the recent New York tubes measurement project have been incorporated into the material provided.

Office of Research and Development
Federal Railroad Administration

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I. INTRODUCTION: DESCRIPTION AND SCOPE

1.1 GENERAL DESCRIPTION AND BACKGROUND

This specification and the accompanying test plan delineate the performance requirements, supporting analyses, and testing requirements which will be used to govern the design, fabrication, and testing of an innovative low-profile, lightweight intermodal railcar, hereafter referred to as "Car." The Car shall be capable of providing improved operational efficiency and service to locations not readily accessible by existing intermodal flat cars. The principal requirement of the proposed Car is a sufficiently low profile that empty and loaded highway trailers and containers of standard dimensions can be transported directly to locations along routes with restricted clearance. It is highly desirable that the profile of the Car and lading be such that it can be operated through the existing railroad tunnels in the New York City area, and in Detroit, Baltimore and Washington, D.C.

The Car shall be fully interchangeable with existing freight cars in North America. The design and construction of the Car shall be in accordance with Assocation of American Railroads (AAR) design, fabrication and construction principles, AAR interchange requirements, and Federal Railroad Administration (FRA) safety standards, unless superseded by this Specification.

The Car shall be capable of carrying empty or loaded standard highway trailers of lengths ranging from 27 feet to 45 feet equipped with front-mounted or under-mounted refrigeration units, or empty or loaded containers ranging in length from 20 feet to 40 feet, whether on or off chassis. It shall be designed for minimum aerodynamic and rolling resistance to minimize energy consumption, and shall be capable of operating at speeds up to 100 mph on Class 6 track.

The Car specified here is an idealized concept which satisfies the most stringent technological requirements presently envisioned for intermodal service. The performance baseline defined here may not be equally appropriate for all users of this Specification, particularly when economic considerations are factored in. Individual users may wish to modify some of the requirements to better reflect their needs; those stated here have no official standing, as such, although they do represent a well-thought-out technical judgement about what characteristics a new intermodal railcar should have.

1.2 KEY ISSUES AFFECTING USE OF THIS SPECIFICATION

The combination of performance requirements contained in this Specification is expected to be technologically feasible, but may be more costly to attain than all potential users would prefer. The key performance requirements which, when taken together, make the design and construction of the Car challenging, are:

clearance profile (height and width)
light weight
high speed (100 mph)
interchangeability.

1.2.1 Performance Trade-Offs

An individual railroad may not consider all of these requirements to be applicable for its own use, and may elect to modify some of them. For example, a railroad which contemplates using the Car in captive unit-train service only would not want to impose the geometric and structural constraints required for interchangeability. (The issue of interchangeability is discussed at greater length in Section 1.2.3.) Similarly, a railroad which does not serve the most restrictive tunnels in the New York metropolitan area and does not contemplate interchange routing of its Cars to that area would be likely to relax the clearance requirements of this Specification. In either case, the relaxation of performance requirements has the potential to reduce the cost of the Car.

Relaxation of requirements in this Specification should not be taken lightly, but should only proceed after a careful cost-benefit tradeoff analysis. A change in one performance requirement could have a profound influence on the choice of the most cost-effective design to meet the Specification. This means that the trade-offs among different combinations of performance requirements may involve the development and costing of detailed design solutions for each case, obviously not a simple procedure since these trade-off analyses and designs must be performed separately for each combination of modified performance requirements. It is not possible to include the trade-offs themselves in the Specification. Should each railroad specify the precise requirements it needed to optimize its own trade-offs, the resultant lack of standardization could produce a multitude of separate designs at a higher final cost than a single, standardized, high-performance design.

1.2.2 Standardization

Standardization of design will be promoted if the key performance requirements are not subject to adjustment. These include the clearance profile, configuration requirements and anticipated loadings. The decision to require that two 20-foot containers weighing up to 64,000 pounds each be accommodated in each space which would otherwise contain one 40-foot container is just such a critical decision because of its strong influence on the gross vehicle weight, and therefore the structural design, of the car. Removal of that requirement would be a fundamental change to this Specification, and would lead to production of a very different Car design.

1.2.3 Interchangeability

The single most significant influence on the design of a Car to meet this Specification is the requirement that the Car meet AAR requirements for interchange on all American railroads. This makes the Car suitable for ubiquitous use in the U.S. and is expected to make it more attractive to the large majority of potential users by eliminating constraints on its use. It ensures compatibility with virtually all other American rolling stock and should make the Car suitable for a much wider potential market than a non-interchangeable car.

While complete interchangeability realistically represents the design and operating philosophy behind the vast majority of current American freight vehicles, it does impose some stringent performance requirements which will make it more difficult and more costly to meet some of the other requirements in this Specification. The constraints imposed by the need to remain interchangeable have led to the development of some very explicit and standard performance requirements which are well recognized in the railroad industry, but which at the same time tend to inhibit the development of innovative designs. The AAR Specifications of Reference Document [1] are the minimum requirements for interchangeability.

A user of this Specification who does not wish to obtain an interchangeable Car could relax the constraints, substituting new values for the appropriate performance measures. The choice of the new baseline values must be based on a detailed study of the anticipated operating conditions for the Car, and will have to be tailored to the particular needs of the railroad making the purchase. It would not be productive to attempt to define a new set of baseline values of the general non-interchange case in this Specification because of the diversity of needs of different railroads.

1.2.4 Purchase and Operating Costs

It is not appropriate to set cost requirements in a performance specification which is intended to be used as part of a competitive procurement process. While it is, of course, desirable to design a Car which can be produced and operated at a minimum cost, any attempt to specify limits on those costs in advance would be highly speculative and unproductive. Maintenance costs are particularly difficult to estimate because of substantial differences in procedures, track quality, operations and cost accounting procedures among various railroads.

1.3 ORGANIZATION OF SPECIFICATION

This Specification is intended to be used in conjunction with its companion volume, the Acceptance Test Plan, which describes the analyses and tests which must be performed to demonstrate compliance with the requirements stated here. The remainder of this volume, the Specification itself, states the performance requirements for the car. These are subdivided as follows:

Section 2 - Vehicle Performance Requirements

Section 3 - Car Body Performance Requirements

Section 4 - Truck Performance Requirements

Section 5 - Requirements for Other Equipment.

Only those requirements which must be considered at the complete vehicle level, such as ride quality, clearances, dynamic stability, etc., are included in Section 2. On the other hand, Sections 3 and 4 contain the requirements for the Car body and trucks as units, respectively. Requirements for other equipment, such as brakes, couplers and draft gear, are contained in Section 5. Section 6 contains explanations of the reasons for including the most significant requirements, so that the user will gain some understanding of how these requirements were developed.

1.4 DEFINITIONS OF TERMS AND ABBREVIATIONS

The following definitions of terms and abbreviations shall apply throughout this Specification unless otherwise noted:

- AAR - Association of American Railroads
- Car - the smallest combination of complete low-profile, light-weight intermodal Car Section(s), including trucks, which will be routinely coupled and uncoupled during railroad operations.
- Car Section - the Car body structure, capable of withstanding in-train and load forces referenced in this Specification. Each Car Section shall be capable of carrying at least one 45-foot trailer or one container, but may be able to carry more than that.
- CFR - Code of Federal Regulations (Reference Document [2])
- Gross Rail Load - the maximum gross weight on the rails per Car. This load is determined from the maximum load allowed per wheel.
- Light Weight - the total weight of the empty Car, including trucks and all appurtenances considered part of the Car. This term is also applied to trailers and containers in this Specification.
- Maximum Design Load - the sum of the maximum gross weights of the heaviest combination of containers and/or

trailers which the Car can carry at any one time.

- Reference Train Set - the combination of intermodal Car Sections and configurations that can carry six 45-foot highway trailers.

- Test Train Set - the number of Cars to be delivered to the purchaser for acceptance testing. The number will be a function of the Car configuration, but will correspond to at least one Reference Train Set.

1.5 REFERENCE DOCUMENTS

The following reference documents are referred to by the numbers shown below throughout this Specification:

[1] "Specifications for Design, Fabrication and Construction of Freight Cars," M1001, Volume 1 Standard; Association of American Railroads, Operations and Maintenance Department, Mechanical Division, 1920 L Street, N.W., Washington, D.C. 20036, effective Sept. 1, 1979. (Section C, Part II of Reference Document [4].)

[2] "Code of Federal Regulations," Section 49-Transportation, Parts 215, 231, 213, 232. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402.

[3] "Field [a] and Office [b] Manuals of the Interchange Rules." Mechanical Division, Operations and Maintenance Department, Association of American Railroads, 1920 L Street, N.W., Washington, D.C. 20036. January 1, 1980.

[4] "Manual of Standards and Recommended Practices." Association of American Railroads, Operations and Maintenance Department, Mechanical Division, 1920 L Street, N.W., Washington, D. C. 20036.

[5] "Installation, Freight Car Brake Equipment, Specification No 2518." As adopted by the Association of American Railroads, Westinghouse Air Brake Division, Westinghouse Air Brake Company, Wilmerding, Pa. 15148.

[6] "Freight Car Hunting Model." Report No. R-251, Association of American Railroads, Research and Test Division, 3140 South Federal Street, Chicago, Illinois.

[7] Fred E. Ostrem and Basil Libovicz, "A Survey of Environmental Conditions Incident to the Transportation of Materials," General American Research Division, General American Transportation Corp. Report 1512-12, Oct. 1971, PB 204 442.

[8] Andrew G. Hammitt, "Aerodynamic Forces on Freight Trains, Volume I - Wind Tunnel Tests of Containers and Trailers on Flatcars," Report No. FRA/ORD-76/295.I, December 1976, PB 264 304.

[9] Andrew G. Hammitt, "Aerodynamic Forces on Various Configurations of Railroad Cars for Carrying Trailers and Containers," Report No. FRA/ORD-79/39, January 1979, PB-80-174881.

[10] Andrew G. Hammitt, "Wind Tunnel Tests of Trailer and Container Models to Determine the Influence of height and Gap Spacings on Aerodynamic Forces," Report No. FRA/ORD-80/51, December 1980.

[11] Klauder and Associates, Louis T.; Washington Metropolitan Area Transit Authority-Specification for 184 New Cars," April 12, 1978, Preliminary Specification for Industry Comments, Philadelphia, Pa.

[12] G. Kachadourian, N.E. Sussman, J.R. Anderes, "FRATE Volume I: User's Manual," Report No. FRA/ORD-78/59, September 1978, PB 291 206.

II. VEHICLE PERFORMANCE REQUIREMENTS

2.1 GENERAL CONSIDERATIONS

The design of the Car shall be the sole responsibility of the Contractor, and it shall be the Contractor's responsibility to provide a Test Train Set of cars, which shall in all respects be suitable for the purposes intended. If any part, device, or assembly is required to make the Test Train Set function as intended, it shall be the Contractor's responsiblility to provide that part, device, or assembly just as if it had been called for in this Specification.

The primary cargo of this Car is assumed to be 40' trailers of width 8' and height 13'6". Much of this Specification focuses on the transport of this cargo, but if the principal use of the Car is anticipated to be for a different size of trailers or containers, that cargo should be chosen as the principal loading condition.

The car shall also be capable of transporting standard containers, either on or off chassis, ranging in length from 20' to 40'; and standard highway trailers in lengths ranging from 27' to 45', of width 8' and a height of 13'6" with front-mounted or under-mounted refrigeration units, as described in Table 2.1. The design of the Car shall be such that two 20-foot containers can be carried in the space allotted for one 40-foot or longer highway trailer.

The efficiency of transport is expected, and allowed to decrease when cargo other than 40' highway trailers are carried.

The Car (including Car body and trucks) shall be designed to have a useful life of 25 years, assuming it travels 100,000 miles per year and is properly maintained.

2.2 CLEARANCE AND CURVE NEGOTIATION REQUIREMENTS (see also Section 2.2.1)

The static physical dimensions and dynamic motions of the Car, trucks and attached equipment shall not exceed the limiting Clearance Outline shown as Figure 2.1 under the most extreme combinations of broken or solid springs, lateral and vertical motions, roll, and worn wheels, while subjected to all combinations of loads, adjusted for actual truck centers using Figure 2.2 and track curvature specified therein.

The Car shall be capable of negotiating the curvatures shown in Table 2.2 below in accordance with the requirements specified in Reference Document [1], Paragraphs 2.1.4 through 2.1.4.4.2.2.

In addition, the ratio of the maximum lateral force on one truck to the light weight of the vehicle on the rail for that truck (truck L/V force ratio) shall not exceed 0.82 when a drawbar pull of 200,000 pounds is applied to the Car on a 10 degree curve as per Paragraph 2.1.6.1 of Reference Document [1].

A minimum clearance of at least 1 1/2" shall be provided between the Car wheels and the Car body under the most extreme conditions stated above. No part of the Car, except wheels, shall be less than 2 3/4" above the top of the rails under any combination of the above conditions, in accordance with AAR requirements, Reference Document [1], Paragraph 2.1.5.1.

The clearance between adjacent Cars (except at the Strikers and Couplers) shall not be less than 3" under maximum buff load conditions, and not less than 1/2" after couplers or drawbars have telescoped and strikers have engaged, under the most restrictive combination of track conditions shown in Table 2.2.

The height from top of rails to the center of the coupler (empty car) shall be 33 1/2" (+1", -0") in accordance with Reference Document [1], Paragraph 2.1.5.2 and Reference Document [3a], Rule 16.E.12; if conventional truck configurations are used, center plate and side bearing heights and clearances shall be in accordance with Paragraphs 2.1.5.3 through 2.1.5.6; the minimum vertical clearance between the truck and the Car shall be in accordance with Paragraph 2.1.5.7.

2.2.1 Clearance Requirements for New York Tunnels

If the design of the Car is to permit operation in North and East River Tubes and Penn Station, New York City, the provisions of Figure 2.3 must be met, in addition to those specified elsewhere herein.

2.3 CONFIGURATION REQUIREMENTS

In actual use the Car may be dedicated to containers or to trailers of a specific length. However, the overall design configuration of the Car shall be such that a conversion for use with any of the container or trailer configurations listed in Table 2.3 would not involve a significant redesign or reconstruction.

The configuration of the Car shall be such that highway trailers and container chassis can be loaded or unloaded using standard overhead lifting equipment or side loaders without raising or lowering the trailer landing legs. Provisions shall be such that containers are accessible by top or bottom loading equipment. Provisions shall be made such that loose trailer or chassis landing legs are prevented from falling to the track.

2.4 INTERCHANGE SERVICE REQUIREMENT

The design, construction, fabrication and testing of the Car shall be executed in a manner such that AAR approval for interchange can be obtained.

2.5 STRUCTURAL REQUIREMENTS

The Car structure shall be capable of carrying the trailers and containers specified in Table 2.3 safely, while simultaneously satisfying all other requirements of this Specification, including the appropriate load factors.

2.6 PRODUCTION VOLUME OBJECTIVE

The design of the Car shall be based on a production volume of 1,000 cars per year.

2.7 DYNAMIC PERFORMANCE REQUIREMENTS

The dynamic performance of the Car shall be such that the forces and accelerations developed inside the trailers or containers carried on the Car do not exceed the levels specified below.

In this Specification, the dynamic performance is divided into three categories: stability (truck hunting and "rock-and-roll"), ride vibration, and impact (humping and train action). In the following paragraphs, dynamic performance requirements are specified for each of these categories.

2.7.1 Stability Requirements

The Car shall be capable of operating in a safe and dynamically stable condition over all Classes of track at the speeds defined in Table 4.1 of this Specification, under all loading conditions.

Table 2.1 Dimensions and Weights of Intermodal Trailers and Containers (1)

LOAD CONDITION		LENGTH	WIDTH	HEIGHT	LIGHT WEIGHT (POUNDS)	MAXIMUM GVW(2) (POUNDS)
A	TRAILERS	27'	8'	13'6"	8,100	38,100
B		40'	8'	13'6"	13,000	73,000
C		45'	8'	13'6"	17,000	77,000
	CONTAINERS					
D	without chassis	20'	8'	8'6"	10,500(3)	64,000
E	with chassis	28'8"	8'	12'10"	20,000	75,000
F	without chassis	35'	8'	8'7"	5,500	55,000
G	with chassis	35'10"	8'	12'11"	11,500	67,000
H	without chassis	40'	8'	9'6"	9,000	69,000
J	with chassis	42'8"	8'	13'6"	18,000	78,000

Note: (1) Source: All dimensions and weights are maximum figures taken from "The Official Intermodal Equipment Register", August 1978. Intermodal Publishing Company, Ltd., 424 West 33rd Street, New York, N.Y. 10001.

(2) GVW - Gross Vehicle Weight

(3) Refrigerated container unit

Table 2.2 Track Configuration Requirements — Low-Profile, Light-Weight Intermodal Railcar

Minimum Radius of Track Curvature (for low speeds in yards)	200 feet
Most Restrictive Crossover (i.e., smallest angle between intersecting tracks)	12° 30'
Maximum Track Superelevation (including 1 inch crosslevel deviation)	7 inches
Maximum Grade	6%
Vertical Radius of Track Curvature	850 ft

Table 2.3 Baseline Loading Conditions for Tests

LOADING CONDITION	NUMBER AND LENGTH OF TRAILERS OR CONTAINERS	WEIGHT OF EACH CONTAINER/TRAILER (LB) **	LOCATION OF LOAD *
A. Configuration accommodating one 40' or 45' trailer per Car Section			
1	One 40' trailer (full)	73,000	Centered
2	One 40' container (full)	69,000	Centered
3	One 40' trailer (empty)	13,000	Centered
4	One 40' container (empty)	9,000	Centered
5	Two 20' containers (full)	64,000	Symmetrical
6	One 20' container (full)	64,000	Asymmetrical (at one end)
7	None (empty Car)	--	--
8	One 40' trailer (half full)	43,000	Centered
B. Configuration accommodating two 40' or 45' trailers per Car Section			
9	Two 40' trailers (full)	73,000	Symmetrical
10	Two 40' containers (full)	69,000	Symmetrical
11	Two 40' trailers (empty)	13,000	Symmetrical
12	Two 40' containers (empty)	9,000	Symmetrical
13	Four 20' containers (full)	64,000	Symmetrical
14	None (empty Car)	--	--
15	Two 40' trailers (half full)	43,000	Symmetrical
16	One 40' trailer (full)	73,000	One end
17	Two 20' containers (full)	64,000	One end
18	Two 20' containers (full)	64,000	Centered

* 40' trailer loadings shall be applied according to Paragraph 4.3.4.1 of Reference Document 1, which specifies:

King pin to nose distance	36"
Rear of trailer to real axle of bogie	27"
Trailer bogie axle center spacing	48"

** Lading shall be of the appropriate density to completely fill the volume of the trailer or container for those conditions labeled "full" (i.e., about 20 lb/ft^3 for 40' containers and trailers and 40 lb/ft^3 for 20' containers).

Table 2.4 Theoretical Train Resistance Requirements (Level, Tangent, Track, No Wind)

TRAIN SPEED (MILES PER HOUR)	RESISTANCE PER TRAILER (LOAD CONDITION B, TABLE 2.1) (POUNDS)
5	75
20	108
40	189
60	321
80	500

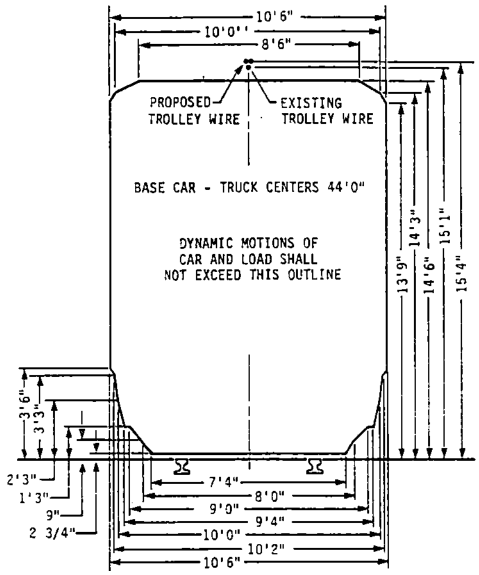
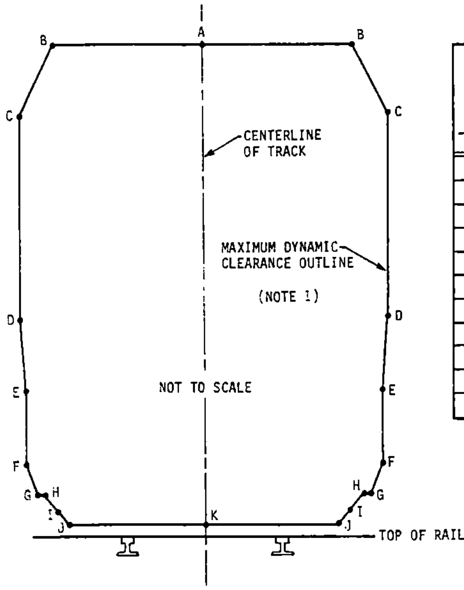


Figure 2.1 Clearance Outline — Low-Profile, Light-Weight Intermodal Railcar (LPLWIR)

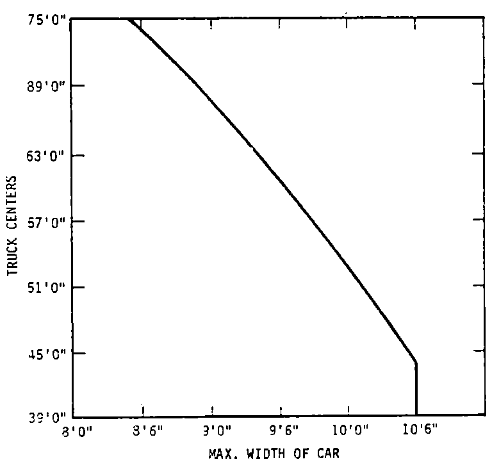


POINT	HEIGHT ABOVE TOP OF RAIL FT.IN.	DISTANCE FROM TRACK VERTICAL CENTER-LINE — FT.IN.
A	13-10	0-0
B	13-10	4-3
C	11-10	5-3
D	6-0	5-3
E	4-0	5-1
F	1-11	5-1
G	1-1	4-9
H	1-1	4-7
I	0-7	4-1½
J	0-2 3/4	3-10
K	0-2 3/4	0-0

NOTES:

1. CLEARANCE OUTLINE REPRESENTS MAXIMUM ALLOWABLE DYNAMIC ENVELOPE PRODUCED BY RAILCAR AND LOADS UNDER MAXIMUM VERTICAL AND LATERAL EXCURSIONS OF THEIR SUSPENSION SYSTEMS, RAILCAR AXLE JOURNAL CLEARANCES AND WHEEL TO RAIL CLEARANCES.
2. MAXIMUM SWINGOUT OF ANY PART OF CAR OR LOAD SHALL NOT EXCEED ONE INCH PER DEGREE OF CURVATURE.
3. REFERENCE: AMTRAK DRAWING SK-A-0922-80,REV.2, SEPTEMBER 24, 1980

Figure 2.3 Clearance Criteria for Flatcars Carrying Trailers or Containers Through North and East River Tubes and Penn Station, N.Y.



THE REDUCTION IN WIDTH IS PREDICATED ON THE BASE CAR, DEFINED ON FIG. 2.1, AND ON A 13° CURVE.

BASE CAR - (EXTREME WIDTH 10' 6") (TRUCK CENTERS 44' 0")

13° CURVE = 441' 3-3/8" RADIUS
MAXIMUM SWINGOUT AT CENTER WITH 44' 0" TRUCK CENTERS= 6-1/2"
(REQUIRES CAR WIDTH 13" LESS THAN MINIMUM WIDTH BETWEEN OBSTRUCTIONS SUCH AS TUNNEL WALLS)

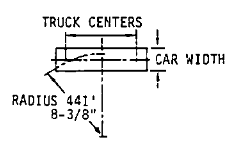


Figure 2.2 Maximum Car Widths Relative to Truck Center Spacings for LPLWIR

2.7.1.1 Hunting

Primary (truck) hunting and secondary (car body) hunting shall not occur below the permissible maximum operating speeds for each Class of track specified in Table 4.1, using either new or worn wheels. The modified Heumann profile, although not a worn profile, is to be used to represent the worn tread. For purposes of this Specification, truck hunting shall be defined as sustained lateral and yaw oscillations of the truck involving loss of tread contact.

2.7.1.2 Rock and Roll

Wheel lift-off induced by "rock-and-roll" motion of Car body and load oscillation shall not occur on any Class of track for train speeds up to the maximum speeds shown in Table 4.1 of this Specification. Additional stability requirements as specified in Reference Document [4] Section D - Trucks and Truck Details, "Specifications for Testing Special Devices to Control Stability of Freight Cars," shall be satisfied. The Clearance Outline of Figure 2.1 shall not be violated by dynamic motions of the Car.

2.7.1.3 Flange Climbing

The ratio of the instantaneous lateral guiding force (L) exerted by a single wheel on the rail to the instantaneous vertical load (V) sustained by that wheel shall not exceed 0.8 for more than 6 feet of track when operating in all loading conditions on tangent track at the maximum speeds permitted by the track class or in curves at speeds up to that corresponding to 3-inch unbalanced superelevation.

2.7.1.4 Rail Overturning

The ratio of the sum of the instantaneous lateral guiding forces exerted on the rail by the wheels on one side of a truck to the sum of the instantaneous vertical loads sustained by those wheels shall not exceed 0.6 for more than 6 feet of track when operating in all loading conditions on tangent track at the maximum speeds permitted by the track class or in curves at speeds up to that corresponding to 3 inch unbalanced superelevation.

2.7.2 Ride Vibration Requirements

The Car shall be designed to provide a ride vibration environment for trailers and containers no more severe than that experienced during typical street or highway operations. The resultant acceleration (based on three orthogonal accelerometer measurements) at all locations on the floor of any trailer or container mounted on the railcar shall at no time exceed 1.0g during constant-speed travel at all speeds up to and including the maximum allowable, for each class of track. The root-mean-square (RMS) values of vertical and lateral acceleration of the trailer or container floor within the frequency range of 0-30 Hz shall not exceed 0.5g and 0.1g respectively under the same constant-speed operating conditions on all classes of track. Resonances with frequencies of 30 Hz or less, measured at the floor of a container or trailer mounted on the Car, shall have damping ratios of not less than 0.2.

2.7.3 Impact Requirements

The Car shall be capable of providing shock protection for the trailers or containers such that the maximum forces permitted by AAR Specifications M-928-75 and M-952-72 (in Section I of Reference Document [4]) for trailer hitches and container securements are not exceeded during the 10 mph impact tests described in the referenced AAR Specifications. In addition, the accelerations measured on the floor of empty trailers (above kingpin and above trailer bogie center) and containers mounted on the Car shall not exceed 10g vertical and 5g longitudinal during the impact test.

2.8 TRAIN RESISTANCE REQUIREMENTS

The theoretical resistance of the Reference Train Set carrying six standard 40-foot highway trailers loaded to the maximum Gross Vehicle Weight, described by Load Condition B of Table 2.1, shall not exceed the values shown in Table 2.4 below when the train is operated over level, tangent track with no wind. This resistance shall be calculated using the equation shown in Paragraph 3.1.7 of the accompanying Test Plan and shall be verified by the test procedure in Paragraph 4.4.6 of the Test Plan.

2.9 CAR WEIGHT REQUIREMENTS

The Light Weight of the Reference Train Set which can carry six 45-foot highway trailers shall not exceed 156,000 pounds.

The maximum axle loading of any axle of the Car at the Gross Rail Load shall not exceed the values in Reference Document [4], Section G, Part II, Wheel and Axle Manual, Paragraph 5.22. Axle load derating guidelines as given in the AAR Wheel and Axle Manual, Paragraph 5.24, for equipment operating at speeds in excess of 85 miles per hour shall be considered.

2.10 SAFETY REQUIREMENTS

The Car shall conform to FRA Safety requirements of Reference Document [2]. Safety Appliances shall be provided in accordance with AAR requirements of Reference Document [1].

Equipment components shall be located so that access to them by the required personnel during operation, maintenance, repair, or adjustment shall not expose personnel to hazards such as entrapment, cutting edges, or sharp points. Suitable warning and cautionary notes for operation, assembly, maintenance, and repair shall be provided. Protective guards shall be provided at entrapment points where practical. In particular, sill steps and handholds shall be located in a manner so as to permit train crew members to get on, to ride, and to get off a moving Car safely.

Uncoupling levers shall be provided on both sides of each end of the Car.

The angle cock shall be operable from either side of the Car such that railroad personnel are not exposed to the ends of the Car during angle cock operation.

III. CAR BODY PERFORMANCE REQUIREMENTS

3.1 GENERAL

Each section of the Test Train Set to be fabricated under this Specification shall be designed to carry trailers ranging in length from 27 feet to 45 feet with front-mounted or under-mounted refrigeration units, and containers 20 feet to 40 feet in length. The maximum gross weight of a trailer or of a container and chassis combination is specified in Table 2.1 of this Specification.

The Car body structure shall be designed in accordance with the AAR "Specifications for Design, Fabrication, and Construction of Freight Cars" (Reference Document [1]) unless otherwise specified herein. In particular, materials used for Car construction shall be of a structural or Car building quality as defined in Section 3.1 of Reference Document [1]. The use of materials other than steel shall be permitted only upon authorization by the purchaser's representative.

Welding, riveting, and bolting methods for steel structures shall be in accordance with Section 5.1 - "Workmanship" of Reference Document [1]. Alternative fastening methods proposed for material other than steel shall be used only upon approval of the purchaser's representative.

The overall configuration of the Car shall be such as to minimize the gap spacing between trailers and containers and between Car Sections under anticipated mixes of trailer and container loads. The car body shall be designed to minimize aerodynamic drag, and the use of air flow control devices is encouraged where practical.

3.2 ARRANGEMENT AND DETAILS

3.2.1 Jacking Pads

Jacking pads shall be provided in four locations on each Car Section as specified in Reference Document [1], Paragraph 4.1.6.
Jacking pads shall be at least four inches by nine inches in size and shall have anti-slip bottom surfaces. The nine inch dimension shall be parallel to the side of the Car. Jacking pad heights shall be in accordance with Reference Document [1], Paragraph 2.1.5.21.

For rerailing purposes it shall be possible to raise one end of the loaded Car with the truck attached by means of a jack placed under the coupler shank.

3.2.2 Safety Appliances

Safety appliances shall comply with AAR Interchange Rules and FRA Safety Appliance Standards, Reference Documents [3] and [2].

3.2.3 Trailer Centering

Rub rails and guidance rails shall be provided at the sides of the trailer wheel platforms such that the trailer wheels are automatically centered on the platform as trailers or containers with chassis are loaded onto the Car.

3.2.4 Drains and Openings

Drains and openings shall be provided on the Car body structure so that water from rain or melted snow can drain freely from the trailer wheel platforms, or so that accumulated snow and ice deposits can be removed readily from the trailer wheel platforms.

3.3 CAR BODY STRUCTURE REQUIREMENTS

3.3.1 Fatigue Requirements

The Car body structure shall be designed in accordance with the guidelines published by the AAR in Chapter VII of Reference Document [1].

3.3.2 Car Body Strength Requirements

The load factors and allowable design stresses for the Car body structure shall be those defined in Section 4.2, "Allowable Stresses," Reference Document [1].

The design loads applied to the structure shall be those loads defined in Section 4.1, "Loads and Forces," Reference Document [1], and in Paragraphs 3.3.3 through 3.3.7 of this Specification, multiplied by appropriate load factors.

3.3.3 Compressive End Load Requirements

The Car body structure shall be designed to sustain a compressive columnar end load of 1,000,000 pounds as specified in Reference Document [1] Paragraph 4.1.9.

3.3.4 Vertical Load Requirements

The Car body structure shall be designed to sustain the worst case vertical loads imposed by trailers and containers listed in Table 2.3 of this Specification.

In addition, the Car body structure shall be designed to withstand the vertical coupler loads and jacking loads specified in Reference Document [1], Sections 4.1.5 and 4.1.6, where the jacking load includes the Maximum Design Load plus the Light Weight of the Car.

3.3.5 Torsional Strength Requirements

The Car body structure, when carrying the heaviest allowable load of trailers or containers (Table 2.3), shall be capable of being lifted on diagonally opposite jacking pads without incurring permanent deformation in any element of the Car body.

3.3.6 Draft Load Requirements

The Car body structure shall be designed to sustain draft (tensile) or buff (compressive) loads of 350,000 pounds as specified in Reference Document [1], Paragraphs 4.1.8 and 4.1.8.1.1.

3.3.7 Impact Load Requirements

The Car body structure shall be designed to sustain the reaction and inertial forces resulting from a single-ended impact as specified in Reference Document [1], Paragraph 4.1.10 and Subparagraphs 4.1.10.1, 4.1.10.2, 4.1.10.3, 4.1.10.-3.6 to 4.1.10.3.6.2, and Paragraphs 4.1.11 to 4.1.11.3.

IV. TRUCK REQUIREMENTS

4.1 GENERAL

Trucks shall be of a design that shall comply with the performance, strength, and ride quality requirements of this Specification, and those of Reference Document [4], Section D - Trucks and Truck Details.

4.2 DESIGN CONSIDERATIONS

4.2.1 Maintenance Provisions

The design of the truck shall provide unobstructed access to all parts which require periodic and in-service inspection, lubrication, removal, or replacement without requiring removal of any other equipment. Lubrication fittings on the truck are to be accessible for servicing from the side of the Car. Brake shoes and pads shall be visible for inspection from the sides of the trucks; brake shoes and pads shall be readily replaceable.

The design of the truck shall be based upon the maximum operating speeds listed in Table 4.1 below.

Table 4.1 Low-Profile, Light-Weight Intermodal Railcar Maximum Operating Speeds

FRA CLASS OF TRACK	MAXIMUM SPEED (MPH)
1	10
2	25
3	40
4	60
5	80
6	100

4.2.2 Hub Odometers

Hub odometers capable of registering total miles of operation in both directions shall be installed on one end of one axle of each Car Section of the Test Train Set. Mounting provisions for hub odometers shall be made on all trucks.

4.3 TRUCK STRENGTH REQUIREMENTS

The truck frame and all truck components shall be capable of withstanding the maximum loads imposed by the forces acting on the assembly, including shocks produced by maximum allowable track perturbation inputs, brake application, and loads transmitted from the car body.

The truck must meet the requirements of Reference Document [4], Sections A and D. The requirements of these specifications shall not be interpreted as discouraging the use of innovative new designs. Flexibility in the specifications is provided by allowing the design, testing and structural materials to be varied with special approval of AAR.

4.4 TRUCK PERFORMANCE REQUIREMENTS

4.4.1 Motion Restriction

The suspension system shall restrict the motion of the Car such that it cannot under any conditions exceed the Clearance Outline shown in Figure 2.1 of this Specification.

The distance from the lowest part of the Car to the plane of the top of the rails must not be less than 2-3/4 inches with truck suspension members solid and under maximum wheel wear conditions, in accordance with AAR requirements.

4.4.2 Truck Equalization

With the truck on level track under empty Car load, truck equalization shall be such that jacking any one wheel 2-1/2 inches vertically shall not cause any other wheel tread to lose contact with the rail; and jacking any one wheel 2 inches vertically shall not result in a change of more than 25% in the weight on any wheel.

4.5 TRUCK COMPONENTS

If an innovative truck design is used, each truck produced for the Reference Train Set shall be subjected to 100 percent radiographic inspection of all welds, whether used for construction or repair. If castings are used, the castings of each truck shall be subject to 100 percent radiographic inspection. Thereafter, at the discretion of the purchaser's representative all welds or castings may be subject to magnetic particle, dye penetrant, or ultrasonic inspection.

4.5.1 Springs

Springs may be in as many stages, in addition to elastomeric cushioning, as the Contractor elects. If standard coil springs are used they shall be manufactured of alloyed steel conforming to the requirements of AAR Specifications No. M-114, latest revision, Reference Document [4].

4.5.2 Wheels

Steel freight Car wheels shall be used in accordance with the latest revision of AAR Specifications M-107 and M-208, Reference Document [4].

4.5.3 Axles

Axle sizes shall be selected in accordance with Reference Document [1], Section 2.1.5.17.

A raised wheel seat roller bearing axle shall be used, and ultrasonically inspected, in accordance with AAR Specification M-101, found in Reference Document [4]. The purchaser's representative may approve deviations from this Specification upon submission of adequate information on alternative proposed axles.

Axles shall be given a magnetic particle inspection following machining.

Axles shall have standard 60 degree lathe centers, and shall be marked in accordance with AAR standards, as given in Section 1 of Section G-II, Wheel & Axle Manual, Reference Document [4].

4.5.4 Roller Bearings

Cars shall be equipped with journal roller bearings approved or conditionally approved by the AAR.

4 5.5 Roller Bearing Adapters

Roller bearing adapter crowns shall be hardened in accordance with AAR Specification No. M-924, Reference Document [4]. Hardened thrust shoulders are acceptable but not required.

V. REQUIREMENTS FOR OTHER EQUIPMENT

5.1 COUPLERS, ARTICULATION JOINTS, DRAFT GEAR AND CUSHIONING DEVICES

5.1.1 General

The couplers, articulation joints, draft gear and cushioning device assemblies shall meet the general requirements for AAR Interchange freight service. Couplers shall be of an approved AAR design and shall be compatible with existing freight Car couplers in interchange service. Draft gear assemblies shall be capable of withstanding normal in-train forces, both in draft and in buff, and shall provide sufficient Car cushioning to absorb impacts in both linehaul and yard operations. The couplers and draft gear shall conform to the current issue of Section B, Couplers and Freight Car Draft Components, of Reference Document [4], unless superseded by Reference Document [1].

5.1.1.1 Arrangement

An AAR-approved standard mechanical freight Car coupler shall be provided at each end of the Car so that the Car can be coupled to standard interchange freight cars. Uncoupling levers shall be provided at both sides of the Car for each coupler. Articulated cars shall incorporate AAR approved articulation joints between Car sections.

5.1.1.2 Strength Requirements

The mechanical coupler and draft gear assembly and the articulation joint (if used) shall be able to withstand loads of 350,000 pounds in compression and 350,000 pounds in tension, as specified in Reference Document [1], Section 4.1.8.

5.1.1.3 Geometric Requirements

The coupler and draft gear and the articulation joints if used) shall be selected so that coupled Cars will be able to negotiate the curves specified in Table 2.2 of this Specification, as well as all normal track irregularities, when all wheels on one Car are fully worn and all wheels on an adjacent Car are new. Curve negotiation shall also be possible when the Cars are coupled with other interchange freight cars, including standard TTAX cars, as specified in Reference Document [1], Section 2.1; in particular, coupler lengths shall be in accordance with Paragraph 2.1.6 and 2.1.6.1.

The lateral gathering range of the couplers shall not be less than two inches (with one knuckle closed) while the coupler is at the required operating height and both Cars are on level tangent track.

5.1.2 Mechanical Coupler

The mechanical coupler shall be of an AAR approved type and shall be fully compatible with interchange freight cars in revenue service. Coupler yokes shall be of an AAR approved type.

5.1.2.1 Operation-Mechanical Coupler

The operation of the mechanical coupler at the ends of the Car shall be completely automatic when coupling. Uncoupling levers shall be provided on both sides of the Car, at both ends of the Car.

5.1.2.2 Operation-Articulation Joint

If an articulation joint is used, it shall be of the type that can be disconnected or connected by using standard railroad freight Car shop equipment.

5.1.2.3 Coupler Carrier

Coupler carriers that meet the geometric requirements of Paragraph 5.1.1.3 of this

Specification shall be provided. The coupler carrier shall support the coupler at its nominal height. Coupler carrier wear plates shall be constructed of 11-14 percent manganese steel, unless otherwise permitted by the purchaser's representative.

5.1.2.4 Wear Plates and Lubrication

Coupler and draft gear pivots and carriers shall be equipped with shims, replaceable cushions, wear plates or other means of compensating for wear. Devices requiring lubrication shall be avoided, if possible, but if required, shall be designed so as not to require lubrication more often than once each year.

5.1.3 Draft Gear

Draft gear shall conform to Section B, "Couplers and Freight Car Draft Components," Reference Document [4], unless superseded by Reference Document [1].

5.1.4 Cushioning

Both non-articulated and articulated Cars shall be provided with cushioning adequate to absorb normal impacts in switching and classification operations. The amount of cushioning provided shall be determined by consideration of the requirements specified in Paragraph 2.7.3 of this Specification, and in Reference Document [1], Sections 4.1.10, 4.1.10.1 and 4.1.10.2.

5.1.5 Trailer Hitches and Container Securement Systems

Trailer hitches and container securement systems shall meet the requirements stated in AAR Specifications M-928 and M-952 respectively (contained in Section I of Reference Document [4]).

Any new, untested hitches or securements shall be tested in accordance with the referenced AAR Specifications.

5.2 BRAKE SYSTEM

5.2.1 General

The Contractor shall be responsible for the coordination and proper installation of all components of the brake system and for its interrelation with other freight cars in interchange service and for the successful functioning and proper performance of the Car in accordance with the requirements of this Specification. The brake system shall conform to the current issue of the AAR's "Manual of Standards and Recommended Practices - Section E," and the FRA's Power Brake Law (Section 49, part 232, of Code of Federal Regulations), Reference Documents [4] and [2].

5.2.2 Fail Safe Design

The brake system shall be inherently fail safe in design, construction, and operation to the degree defined in this Specification.

The brake system shall apply all brakes in the train automatically in the event of an unintentional train separation or brake pipe rupture.

Brake system components shall comply to AAR Specification No. 2518, "Freight Car Braking Equipment Installation Specifications," Reference Document [5]. Provisions shall be made for angle cock operation on either side of the Car.

5.2.3 Net Braking Ratios

Brake system components shall be selected to provide the Net Braking Ratios specified in Reference Document [4]. If other than on-tread brakes are used, the braking characteristics of the Car shall be equivalent to those implicit in the AAR Net Braking Ratio Specifications.

5.2.4 Brake Rigging

Cars shall be equipped with brake rigging of AAR approved design. Brake shoe and pad forces shall be developed uniformly during brake application. The brake rigging shall be designed to apply brakes on all wheels of the Car during pneumatic brake applications.

Brake shoes and pads shall be located such that the amount of wear is easily visible from the side of the Car, and so that shoes and pads can be replaced readily in service.

5.2.5 Brake Shoes and Pads

Cars shall be equipped with high friction, composition brake shoes or pads of AAR approved material and design. Brake shoe heads which reject the application of low friction, metal shoes shall be incorporated.

5.2.6 Hand Brake

The hand brake shall be capable of exerting the net shoe forces, expressed as a minimum percentage of gross rail load, specified in Section E of Reference Document [4]. These shoe forces shall be maintained as a minimum under the worst-case condition of fully worn brake material and fully worn wheels.

A hand brake indicator or annunciator that provides an indication when the hand brake is applied shall be provided for each hand brake.

5.2.7 Brake Pipe Fittings

Welded brake pipe fittings shall be used exclusively and shall conform to AAR requirements of Reference Document [4].

5.2.8 Maintenance Requirements

Brake shoe and pad material wear rates shall not exceed those specified in Reference Document [4].

5.3 MATERIALS AND WORKMANSHIP

All materials and workmanship entering into the fabrication of the Cars shall be in accordance with Reference Document [1], Part V - Fabrication and Construction, unless written approval for substitution is obtained from the purchaser's representative.

5.3.1 Painting

All metal portions of the Car Sections shall be given two coats of primer, proper surfacing and two coats of enamel paint.
Wheels shall be suitably protected during painting to avoid paint being deposited on rims and treads.

5.3.2 Stenciling

Stenciling shall be applied to the Car body in accordance with AAR Interchange rules, and the AAR "Manual of Standards and Recommended Practices - Section L," current issue, Reference Documents [3] and [4].

5.4 DRAWINGS AND DIAGRAMS

5.4.1 Engineering Drawings

Four copies of complete and comprehensive Engineering Drawings of the Cars shall be submitted to the purchaser's representative. At a minimum, these drawings shall include all materials, bolt locations, welds, tolerances, and bills of materials.

5.4.2 AAR Interchange Approval

An application for AAR Interchange Approval of the Car shall be made to the Executive Director of the Mechanical Division of the AAR as specified in Reference Document [1], Section 1.2, Paragraph 1.2.2 - Procedure for Approval.

An official notice of AAR Interchange Approval of the Car shall be provided to the purchaser's representative.

5.4.3 Maintenance Manuals

A set of Maintenance Manuals shall be provided for each Car. At a minimum, these manuals shall include recommended bolt torques, lubrication points and intervals, necessary adjustments, cautionary notes, and detailed descriptions of required periodic inspections.

5.4.4 Car Data Books

A Car Data Book shall be provided for each Car of the Test Train Set. The Car Data Book shall contain, at a minimum, the following items and data:

- Photographs of eight inches by ten inches in size to show sufficient viewpoints so that a permanent record of Car assembly is recorded.
- Serial numbers, manufacturer, class, type, size, and materials of all serially numbered apparatus on each Car Section.
- Documentation of all Car and component test results.
- The weight of each Car Section.
- All changes applied to any Car section which have not been applied to all Car Sections.
- A list of all materials used in the fabrication of the Car.
- Additional items specified by the purchaser's representative.

VI. RATIONALES FOR AND EXPLANATIONS OF SPECIFIED REQUIREMENTS

Introduction

The objective of this Specification is to provide design requirements for a new intermodal railcar that has improved operating efficiency and which can provide service to locations not readily accessible with existing intermodal flatcars. To achieve this objective, preliminary quantitative values or ranges of values had to be selected for each of the specified requirements. Selection of values was based either on the requirements of present day equipment or on values that moderately exceed present day requirements. When values that exceed present day requirements were selected, an engineering analysis or rationale was used to justify the values. In the remainder of this section, the engineering analysis, documentation, and rationale used to determine each selected value is explained under the appropriate Reference Paragraph of this Specification.

Reference Paragraph 1.2.4 - Purchase and Operating Costs

As a point of reference, it should be noted that John Angold, the developer of the Santa Fe 10-PACK, estimated that a Car which meets this Specification would cost between $26,000 and $28,000 per Car section (single trailer capacity) to produce in 1980, and maintenance would be of the order of 4 cents per Car section mile.

Reference Paragraph 2.1 - General Considerations

Mr. Angold estimated that a Car of this type should have a service life of 20-25 years if reasonably maintained. He pointed out that Trailer Train cars average 70-75,000 miles per year, while the 10-PACK averages 160,000 miles per year. William E. Thomford, Manager of Technical Research and Tests at Southern Pacific, estimated that a well-utilized intermodal Car would expect to see about 100,000 miles of use per year.

Reference Paragraph 2.2 - Clearance Requirements

The clearance outline described by Figures 2.1 and 2.2 was developed from three sources of data. The outline from the top of the rail to a height of 13' 9" was developed by the Engineer of Clearances and Tests at Amtrak from the North River and East River tunnel data. The corner contour from a height of 13' 9" to 14' 6" is the same as that of the AAR Plate B. (Source: Supplement to AAR Manual of Standards and Recommended Practices). The maximum height of 14' 6" was based on recent tunnel measurements made by the firm of Sverdrup and Parcel.

The minimum clearance requirements defined in Section 2.2 consist of the AAR requirements in Reference Document [1], Section 2.1. The clearance outline described by Figure 2.3 and Section 2.2.1 for the New York tunnels was provided by the Engineer of Clearances, and tests at Amtrak based upon North River and East River tunnel measurements taken in July 1980.

The minimum track configuration dimensions were selected from the track configurations of the Northeast Corridor, and main line railroad tracks throughout the United States.

Reference Paragraph 2.4 - Interchange Service Requirements

In Paragraph 2.4 the requirement for an AAR interchangeable or non-interchangeable Car had to be determined. The advantage of an interchangeable Car is that the total potential market for the Car could be much greater than if the Car were not interchangeable. The obvious benefit of a design that is not interchangeable is the possible reduction in weight resulting from a relaxation of the strength requirements. Further discussion of the interchange service requirement may be found in Section 1.2.3.

Reference Paragraph 2.7.1 - Stability Requirement

Hunting oscillations impose serious limitations on achieving high speeds. In addition, the dynamic wheel-rail forces resulting from hunting oscillations can lead to derailments, damaged lading and rapid wear of freight Car components and structure. Hunting oscillations of the freight Car reveal a loss of dynamic stability. Factors influencing this instability include high speed, the conicity of the wheels, the forces acting between the wheels and the rails, and the reaction of suspension elements. Two very different modes (car body hunting and truck hunting) are frequently observed. Hunting is an inherent characteristic and will inevitably occur with all conventional railway vehicles. However, the critical speed at which this behavior first occurs can be increased beyond normal operating speeds by proper selection of values for design parameters such as wheel tread profile, suspension characteristics, truck geometry, freight Car weights, and proper maintenance.

Several computer models (e.g., the Freight Car Hunting Model [6] developed by the AAR) have been developed to predict the critical velocity at which oscillations become unstable. These computer models can be used as design tools to investigate how the critical speed of hunting is influenced by varying suspension system parameters. Optimum values for suspension parameters and truck geometry can thus be determined to provide sufficient damping to eliminate Car section (secondary) hunting and truck (primary) hunting at speeds below 100 mph.

"Rock and roll" response of a freight car occurs when the carbody rolls so substantially relative to the truck(s) that the carbody centerplate partially or completely lifts off the truck bolster which supports it. This type of severe roll resonance response is typically produced by the alternating track crosslevel inputs associated with low joints on staggered 39-foot rail sections, and is most serious at the speed which generates inputs at the carbody roll resonant frequency. It is generally a more serious problem at lower speeds than at the highest speeds, requiring that it be checked for over the full operating speed range of the Car. Rock and roll responses can cause lading damage, excessive suspension wear and possibly even derailments in the worst cases. A standard set of test conditions (track geometry perturbations and speeds) for the rock and roll phenomenon may be found in the AAR "Specifications for Testing Special Devices to Control Stability of Freight Cars," in Section D of Reference Document [4]. These procedures must be modified to be applicable to an intermodal Car rather than the hopper car which was specified.

Analysis of flange climbing derailment remains very much a research topic, and a consistent, comprehensive theory upon which a detailed specification could be based does not yet exist. The limitation of the L/V force ratio per wheel to 0.8 or less, to discourage flange climbing derailments, was adapted from the AAR "Performance Guidelines, High-Performance/ High-Cube Covered Hopper Car, 100 Tons or Greater," March 1980 Final Draft. This was cited by Mr. William P. Manos as the most up-to-date requirement available addressing flange climbing.

The rail overturning requirement is needed to ensure that the Car does not impose excessive forces on the rails, which would increase maintenance expenses and the incidence of derailments. The requirement stated in the Specification was based on the same AAR Guidelines as flange climbing requirements, again following the recommendation of Mr. William P. Manos.

Reference Paragraph 2.7.2 - Ride Vibration Requirements

The ride vibration environment of primary importance is that of the goods being transported. The diversity of the goods carried in intermodal service is so great that it is not practical to characterize them individually and develop an explicit damage-avoidance ride vibration standard analogous to the I.S.O. passenger comfort standards. Because intermodal operations involve movements both on the highway and on the railcar, a good reference point for railcar ride vibration limits is the vibration environment experienced during normal highway transport. The trailer or container, when mounted on the railcar, should experience a ride equal to or better than that experienced in highway operations.

An adequate description of the vibration environment aboard a highway trailer, which could serve as a baseline case, does not appear to be available. The data which have been published on highway trailer vibrations have generally been incomplete and statistically dubious. Perhaps the most comprehensive collection of these data can be found in Reference Document [7], but even these are not adequate for use here.

The ride vibration requirements must guard against several potential ways of causing damage to lading during mainline railroad operations on track of typical condition. The maximum resultant acceleration of 1.0g is specified to avoid bouncing the lading out of its original configuration and to avoid impacts of units of lading within the trailer or container which could then substantially exceed 1.0g. The limitations on allowable rms acclerations are needed to ensure that the amount of vibration energy transferred to the lading over extended periods of travel is not excessive. Only the frequencies up to 30 Hz need to be considered here because higher frequency vibrations involve very small amplitude displacements and are therefore readily damped by most packing materials. The levels of rms acceleration to permit are difficult to choose on the basis of the available data; those which are cited in this specificaion were based on a cautious interpretation of some of the data for tractor-trailers presented in Reference Document [7]. The vertical accelerations, which are less potentially damaging to stacked cargo than lateral accelerations, were found to be significantly higher in the reported tractor-trailer measurements. The prohibition against lightly-damped response modes is used to supplement the rms acceleration limits in the absence of more suitable power spectral density (PSD) data. This prohibition is needed to ensure that a large fraction of the allowable (RMS) acceleration energy is not transmitted within a narrow frequency band, where lading resonances could produce severe responses, leading to damage problems. Such a restriction would normally be incorporated into an acceleration PSD specification (and appropriately so), but the data needed to formulate such a specification are not available.

Reference Paragraph 2.7.3.- Impact Requirements

The most severe shock loads imposed on trailers and containers used in intermodal service are those experienced in Car to Car impacts due to train action and yard operations. Shock spectra for tractor-semitrailer trucks operating on a variety of road surface disturbances (Reference Document [7]) show acceleration components as high as 10g vertical and 5g longitudinal. Considerations of lading and trailer/container structural integrity would not require lower shock levels on the railcar than those experienced in road operations. However, the trailer hitches and container securements are designed to withstand kingpin forces of 210,000 pounds and longitudinal restraining forces of 121,000 pounds repectively, under the AAR Specifications M-928-75 and M-952-72. For fully loaded containers of load condition H on Table 2.1, this corresponds to approximately 1.75g, and for fully loaded trailers of load condition C it corresponds to about 2.75g. On the other hand, for the lightest empty trailers and containers (load conditions A and F), these correspond to 25g and 22g, respectively. Therefore, it is necessary to impose the maximum acceleration limits of 10g vertical and 5g longitudinal in addition to the force limits.

Reference Paragraph 2.8 - Train Resistance Requirements

To establish theoretical resistance requirements for the Reference Train Set, an equation that contains the necessary parameters for rolling resistance and air resistance was required. In particular, the variations in air resistance affected by Car height and trailer spacing had to be expressed mathematically. Although no equation containing the variations of these parameters was available, Reference Documents [8] and [9] appeared to have the wind tunnel test data necessary to develop such an equation. In this study the aerodynamic resistance of trailers and containers on flatcars was measured for a variety of configurations by testing models in a wind tunnel. The correlation of wind tunnel resistance to total train resistance was assumed to fit best with the "modified Davis" formula.

The "modified Davis" formula can be expressed in the following manner.

$$R = 0.6 + \frac{20}{W} + 0.01\ V + \frac{KV^2}{WN} \qquad (1)$$

where: R = Car resistance in pounds per ton of Car weight
W = Weight in tons per axle (average)
N = Number of axles per Car
V = Velocity in miles per hour
K = Aerodynamic coefficient

In Reference Document [8], the relation between K, the resistance coefficient of the "modified Davis" formula, and C_dA, the drag area is given as:

$$391.1K = C_dA \ (ft^2)$$

or
$$K = \frac{C_dA}{391.1} \qquad (2)$$

Eq. (1) can be written as:

$$R = 0.6 + \frac{20}{W} + .01\ V + \frac{C_dA}{391.1} \quad \frac{V^2}{WN} \qquad (3)$$

Car Height Factor

In Reference Documents [8] and [10], wind tunnel tests were carried out on 1/43 scale models of 40 ft x 13.5 ft (height) x 8 ft (width) trailers on a TTAX flat Car (2 trailers per car), with a height from top of rails to top of trailers of 16.5 ft and an average gap space, between trailers, of 7.16 ft.

Since the A term of C_dA represents the frontal area of the railcar plus trailer, it is a function of the width and height of both. Therefore, if it is assumed that the widths are constant for various intermodal Car configurations, the air resistance will vary directly with height and Eq. (3) can be modified as follows:

$$R = 0.6 + \frac{20}{W} + 0.01V + \frac{C_dAV^2}{391.1\ WN} \quad \frac{(H)}{(16.5)} \qquad (4)$$

where: H = Height from top of rail to top of trailer in feet.

Trailer Spacing

The change in coefficient, C_d, as a function of the spacing ratio (spacing/width) for simple blocks representing standard 40 foot containers was measured in the wind tunnel by Hammitt. If it is assumed that an equivalent change in drag coefficient would occur when the spacing between trailers on railcars varied, a spacing modification can be developed for the "modified Davis" formula.

Coefficients were determined for the best fit of the C_d vs. gap ratio relationship in the absence of a cross-wind component (based on Figure 31 of Reference Document [8]), resulting in:

$$C_d = 0.085 + 0.327\ G_r, \quad .1 \leq G_r \leq 2 \qquad (5)$$

where: C_d = drag coefficient

G_r = gap ratio = gap space/block width.

From Figure 22, Reference Document [11] and Figure 52, Reference Document [8], for 40 ft trailers on TTX flatcars,

$C_d'A$ = 27 ft^2 per tailer, at 0 angle of yaw (no cross wind)

with G_r', average gap ratio $\approx \frac{7.16}{8.0} = 0.9$.

Substituting Eq. (5), the following normalized relationship between $C_d'A$ and G_r' can be written:

$$\frac{C_dA}{(0.085 + 0.0327\ G_r)} = \frac{C_d'A}{(0.085 + 0.0327\ G_r')} \qquad (6)$$

Substituting values for $C_d'A$ and G_r' into Eq. (6) gives:

$$C_dA = 20.06 + 7.72\ G_r \qquad (7)$$

By substituting G_r with the ratio of gap spacing, S, to block width for an 8 ft wide trailer, this equation becomes:

$$C_dA = 20.06 + 0.97\ S \qquad (8)$$

where: S = gap spacing betwen trailers in feet.

Finally, Eq. (8) was substituted into Eq. (4) to obtain the following:

$$R = 0.6 + \frac{20}{W} + 0.01\ V$$
$$+ \frac{V^2}{WN} \ \frac{(20.06 + 0.97\ S)}{391.1} \ \frac{(H)}{(16.5)}, \ 1 \leq S \leq 16 \qquad (9)$$

Eq. (9) was developed as a theoretical means of evaluating train resistance per trailer (forward facing), with fully loaded cars at 0 angle of yaw.

In Table 2.4, "Theoretical Train Resistance Requirements," the values presented are based on the Santa Fe articulated intermodal flatcar, each Car carrying a 40' trailer at Maximum Gross Vehicle Weight.

For comparison, the resistance values in Table 6.1 are calculated for the TTAX type flatcar, which is designed to carry two 40' trailers, and for the Santa Fe 6-PACK. It should be noted that the resistance given is per trailer.

The light-weight, low-profile design of the Santa Fe Car provides a modest reduction in resistance relative to the conventional TTAX Car. The Santa Fe Car displays lower resistance mainly at the higher speeds, where the aerodynamic effects dominate. This is because of the much

Table 6.1 Theoretical Train Resistance (No Wind) Cars Carrying 40-Foot Trailers Loaded to Maximum Gross Weight

TRAIN SPEED (MILES PER HOUR)	RESISTANCE PER TRAILER (POUNDS) SANTA FE 6-PACK	TTAX
5	75	76
20	108	109
40	189	207
60	321	354
80	500	525

lower profile (leading to a smaller total cross-section area) of the Santa Fe Car.

The focus here is on the aerodynamic resistance of the Car, since that is the factor which is most influenced by the Car's design configuration. Rolling resistance is much less affected by changes in Car design, and is particularly sensitive to track condition. As explained in Reference Document [12], the sensitivity of rolling resistance to track condition makes it very difficult to obtain meaningful test data for rolling resistance, particularly if the data are to be used to compare different vehicles operated on different sections of track.

Reference Paragraph 2.9 - Car Weight Requirement

Since a Car body design was not available, selection of the Light Weight of 26,000 pounds per trailer space (156,000 pounds per Reference Train Set) was based on the rationale discussed below.

The Light Weight of the Santa Fe 10-PACK, an articulated intermodal Car which carries ten trailers in a captive, unit-train service (not interchangeable), was used as a basic design objective for minimum weight. John Angold, developer of the 10-PACK, indicated that its Light Weight is 213,500 pounds, or 21,350 pounds per trailer. The end units are heavier than the center units of the 10-PACK, so that a Car having fewer sections would be expected to weigh more per Car Section. In addition, the 10-PACK was not designed for the loads required by interchange service, and therefore does not have the structural strength that this Specification requires. The clearance requirements of this Specification may impose additional structural burdens, further increasing the minimum reasonable weight. This combination of factors has led to the selection of a Light Weight per trailer space of 26,000 pounds, which is about 22% greater than the baseline Light Weight of the Santa Fe Car. This corresponds approximately to the weight per trailer Mr. Angold quoted for the Pullman experimental TOFC car.

Reference Paragraph 4.3 - Truck Strength Requirements

The truck strength and related test requirements developed for this Specification were selected so as not to preclude the possibility of an intermodal Car having a truck design that is different from the design of the standard freight truck composed of side frames and bolster.

Reference Paragraph 4.4.2 - Truck Equalization Requirement

The equalization requirement was developed for rapid transit car trucks to help prevent derailments. It is a recommended requirement for any innovative truck design that might be suggested for use on the proposed Car.

Reference Paragraph 5.1.1.2 - Strength Requirement

The strength requirements of the mechanical coupler, draft gear and articulation joint (if used) were selected on the basis of AAR Car structure requirements for the front or rear draft lugs. See Reference Document [1], Section 4.1.8 - Draft Load.

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US DOT, FRA, RL Hull, SE Shladover