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RAIL SAFETY/EQUIPMENT CRASHWORTHINESS

Volume III: Proposed Engineering Standards

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16. Abstract
The Department of Transportation, Transportation Systems Center (TSC), is providing technical assistance to the Federal Railroad Administration (FRA) in a program to improve railroad safety and efficiency by providing a technological basis for improvement and possible regulation in rail vehicle crashworthiness, inspection and surveillance of equipment, and other areas. As part of this program, TSC has conducted technical analyses of passenger railcar collisions, derailments, and other accidents, directed towards minimizing occupant injuries.

This document, the third of four volumes, contains recommended Engineering Standards prepared in the format of the standards published in the Code of Federal Regulations (Title 49, Transportation, Parts 200). The standards proposed provide improved occupant protection in the secondary impact situation associated with railroad accidents.

Volume I reports on the collection of data for a representative accident sample. Volume II is a design guide to assist engineers in understanding the problems associated with the development of crashworthy interiors of locomotives, cabooses, and passenger railcars. Volume IV is an executive summary.

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Preface

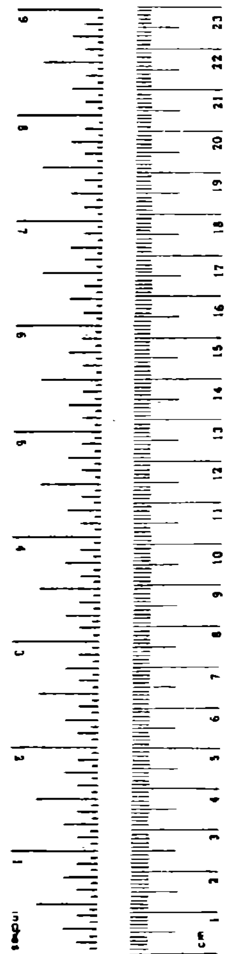
As part of a program to provide a technological basis for improvement in rail vehicle crashworthiness, inspection of equipment, surveillance of equipment and other areas, Transportation Systems Center has conducted technical analyses of passenger carrying rail vehicle collisions, derailments and other accidents.

This document contains proposed engineering standards prepared in the format of the standards published in the Code of Federal Regulation Title 49. The author would like to acknowledge the advice on presentation techniques and content provided by J. H. Wiggins Company of Redondo Beach, California.

METRIC CONVERSION FACTORS

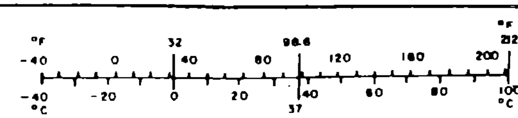
Approximate Conversions to Metric Measures

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



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	35	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



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INTRODUCTION

The following engineering standards are proposed as areas where substantial improvements could be provided in occupant protection in intercity passenger carrying vehicles. The classes of vehicles included are locomotives, cabooses, and passenger railcars.

The standards have been prepared in the format of the standards published in the Code of Federal Regulations, Title 49, - Transportation Parts 200. The part numbers selected are representative only and were selected as being the next available numbers at the time of preparation of the original documents. The parts proposed for inclusion in Chapter 11 of Title 49 are detailed in the main body of this report and listed below for reference.

PART 253 - Rail Vehicle Occupant Collision Containment Standards

PART 254 - Rail Vehicle Occupant Impact Protection Standards

PART 255 - Railcar Seating System Standards

PART 256 - Trainmen Seat Belts Standards

PART 257 - Rail Vehicle Window Standards

PART 258 - Flammability of Interior Materials

PART 253 - RAIL VEHICLE OCCUPANT COLLISION CONTAINMENT STANDARDS

253.1 Purpose and Scope

This part prescribes requirements for provisions to contain rail vehicle occupants within their seated area during collisions for the purpose of reducing occupant accelerations and preventing impact with hostile surfaces.

253.2 Application

This part applies to all locomotives, cabooses and passenger railcars manufactured or refurbished after January 1, 1978 which are used in interstate service.

253.3 Definitions

Restraint - A restraint is any means used to inhibit body motion away from the seated position during a collision, with the objective of preventing impact with hostile surfaces, thereby reducing injuries and fatalities.

Active Restraints - Active restraints are those which must be willfully applied.

Passive Restraints - Passive restraints are those whose application requires no action by the individual being protected.

Containment - The means for limiting the distance an occupant can travel from the seated area to an impact with non-hostile surfaces. Passive devices are used to achieve containment.

Hostile Surface - Surfaces impacted by occupants during a collision which produce injury.

Seat Belt Assembly - Any strap, webbing, or similar device designed to secure a person in a rail vehicle in order to mitigate the results of any accident, including all necessary buckles and other fasteners, and all hardware designed for installing such seat belt assembly.

Pelvic Restraint - A seat belt assembly or portion thereof intended to restrain movement of the pelvis.

Upper Torso Restraint - A portion of a seat belt assembly intended to restrain movement of the chest and shoulder regions.

Attachment Hardware - Any or all hardware designed for securing the webbing of a seat belt assembly to a rail vehicle.

Adjustment Hardware - Any or all hardware designed for adjusting the size of a seat belt assembly to fit the user, including such hardware that may be integral with a buckle, attachment hardware, or retractor

Retractor - A device for storing part or all of the webbing in a seat belt assembly.

Emergency-Locking Retractor - A retractor incorporating adjustment hardware by means of a locking mechanism that is activated by vehicle acceleration, webbing movement relative to the vehicle, or other automatic action during an emergency and is capable when locked of withstanding restraint forces.

253.4 Locomotive Occupant Containment Requirements

253.4.1 Design Requirements

Locomotive trainmen stations shall be provided with a containment system to limit forward displacement of the occupant during forward collision accelerations. The system shall prevent the occupant from leaving the seat and shall prevent the occupant's torso or head from contacting hostile equipment structure or furnishings forward of the seat. The system shall be of the passive type, requiring no actions on the part of the locomotive occupants to utilize the system. It shall be fixed or built into the locomotive in a manner so that it can not be removed by simple tools and shall be designed to withstand an impact force of 2000 pounds without failure.

The distance of the containment device shall not be greater than ten inches forward of the seat reference point (intersection of seat cushion and seat back) with the seat in the most forward adjusted position. Impact of the occupant withthe containment device shall occur at or about the center of gravity of the occupant (ten inches above the seat cushion). The impact force shall be distributed over a minimum of 72 square inches of the occupants torso. The impact surface shall be designed for a spring rate not exceeding ten pounds per square inch per inch for a light weight 150 pound male occupant impacting at a velocity of 150 in./sec. The surface shall compress a minimum of 3.5 inches through the linear range before fully compressing.

253.4.2 Performance Requirements Locomotive Occupant Containment

The locomotive occupant containment device shall be tested by applying a 1740 pound force to the device over an area of 72 square inches. The force shall be applied in ten percent increments and the corresponding deflections measured and recorded. The force deflection curve produced shall be linear within plus or minus ten percent after the load reaches the 30 percent level. Deflection at the 30 percent load level shall not be greater than 50 percent of the full load deflection distance. The spring rate in the linear range shall not exceed ten pound/ $inch^2$/inch.

253.5 Caboose Occupant Containment Requirements

253.5.1 Design Requirements - Seat Containment

Caboose trainmen stations shall be provided with a containment system to limit forward displacement of the occupant. The system shall prevent the occupant from leaving his seat and shall prevent the occupant's torso or head from contacting equipment, structure or furnishings forward of the seat. In the event that the station is designed for use in either forward or rearward operations, the impact protection provisions apply for both directions of operation.

The containment system shall restrain the occupant to the seat by means of a pelvic and upper torso restraint. The pelvic restrain shall be attached to the seat at a point 2.5 ±0.5 inches forward of the seat reference point. The upper torso restraint, consisting of a strap over both shoulders of the caboose occupant, shall be served by a single emergency locking retractor located on the centerline of the seat back at a point positioning the straps 26 ±0.5 inches above the seat reference point. Provisions shall be made to attach the ends of the upper torso shoulder straps to the pelvic restraint lap belt. Design load requirements for the restraint system shall be 15G from a 200 pound (95th percentile) male occupant. Restraint system includes all webbing straps, anchor fittings adjusters attachment buckles, and retractor. Detail requirements for restraint systems are discussed in Part 256.

253.5.1.1 Performance Requirements - Seat Containment

The restraint system test specimen shall be installed on the test fixture at the same geometrical points as installation on a caboose seat. Load shall be applied to the system by a body block of the approximate form and dimensions of the torso of a 95th percentile male. Application of the load shall be in a forward direction at the occupant center of gravity which is ten inches above the seat cushion. A load of not less than 3000 pounds shall be applied without failure of any of the system components. A maximum elongation of seven percent is permissable in the webbing measured from a point after an initial load of 100 pounds is applied, to the point when full load is applied.

253.5.2 Design Requirements - Bunk Containment

Caboose bunks shall be oriented in a longitudinal direction. Containment shall be provided in the form of a barrier at each end of the bunks to prevent ejection of the occupant during a collision or slack action. The barrier shall be designed to withstand an impact force of 2000 pounds applied over a 12 x 12 inch area at both ends of each bunk. The barrier shall be designed for a spring rate not to exceed twelve pound per square inch per inch for a light weight 150 pound male occupant impacting at a velocity of 150 inch/second. The surface shall compress a minimum of five inches through the linear range before fully compressing.

A minimum of two inches of padding shall be provided on the closed side of the bunk. On the open side of the bunk lateral containment shall be provided with two resilient vertical members placed one-third the length of the bunk from each end on the open side. The vertical members shall have a minimum width of four inches and each shall be designed for a concentrated load of 500 pounds applied at the center of each vertical member.

253.5.2.1 Performance Requirements - Bunk Containment

A force of 1110 pounds shall be applied over a 5 x 5 inch area to the containement panel at each end of the bunk. The force shall be applied in ten percent increments and the corresponding deflections measured and recorded. The force deflection curve produced shall be linear within plus or minus ten percent after the load reaches the 30 percent level. Deflection at the 30 percent load level shall not be greater than 60 percent of the full load deflection distance. The spring rate in the linear range shall not exceed twelve pound/inch^2/inch.

A 500 pound load shall be applied to the center of the vertical containment members. Deflection shall be a minimum of four inches and a maximum of twelve inches.

253.6 Passenger Railcar Occupant Containment Requirements

253.6.1 Design Requirements - Seated Occupant Containment

Maximum utilization shall be made of the furnishings in the vicinity of the seated occupant for collision containment. Bulkheads, partitions, seats, windows, wainscoting and the underside of luggage racks shall be designed to provide crashworthy containment during collisions.

Bulkheads located in front of passenger seats shall perform a containment function and shall be located a maximum distance of 14 inches from the front edge of the seat pan. The bulkhead shall be designed to withstand impact loads of 1200 pounds applied at the center of the bulkhead on the center line of both occupants simultaneously. The bulkhead shall have a spring rate in the general areas 20 inches above the floor and 40 inches above the floor of 450 pound/inch maximum with an impact area of seven square inch. The bulkhead shall compress a minimum of two inches in these areas when impacted by the head and knees of a 150 pound average weight passenger at a velocity of 95 inch/second.

Wainscoting shall be designed for a maximum spring rate of 13 pound/inch^2/inch for an average weight occupant impacting at a velocity of 95 inch/second. The surface shall compress a minimum of two inches through the linear range before fully compressing.

All transitions from the wainscoting to the window sash shall be void of sharp edges. A minimum radius of two inches shall be used for all outside corners.

Design of luggage rack underside, seats, and window glazing shall be in accordance with the requirements specified in Sections 254, 255 and 257 respectively.

253.6.1.1 <u>Performance Requirements - Seated Occupant's Containment</u>

Bulkheads, partitions and wainscot in the vicinity of passenger seats shall be tested to determine adequate strength and energy absorbing qualities. Bulkheads and partitions in front of the seat shall be tested by applying a force of 450 pounds over a flat circular area with a diameter of three inches. The force shall be applied simultaneously to four locations as follows: on the centerline of both seat occupants at points 20 inches and 40 inches above the floor. The bulkhead shall withstand the total loading without failure and shall cause a minimum deformation of two inches and a maximum of six inches.

The force shall be applied in ten percent increments and the corresponding deflections measured and recorded. The force deflection curve produced shall be linear within plus or minus ten percent after the load reaches the 30 percent level. Deflection at the 30 percent load level shall not be greater than 50 percent of the full load deflection distance. The spring rate in the linear range shall not exceed 400 pound/inch when the load is applied over each three inch diameter area.

The wainscot shall be tested by applying a force of 900 pounds over a circular area of seven inch diameter at a point 20 inches above the floor. There shall be a minimum penetration of two inches and a maximum penetration of four inches under the applied load.

253.6.2 <u>Design Requirements - Standing Occupants Containment</u>

Areas of passengers cars normally occupied by standing passengers such as snack bars, club car bars, etc., shall be compartmented with partitions at each end of the area to limit the distance occupants can be thrown during a collision. The partitions shall be designed for a maximum spring rate of 1050 pound/inch for a force of 2100 pounds applied over an area of 144 square inches. The surface shall deform a minimum of two inches through the linear range without failure under the impact load.

Bulkheads and doors located at the ends of passenger cars shall be designed to reduce the impact loading on occupants that strike these surfaces during a collision. The bulkheads and doors shall be designed for a maximum spring rate of 3000 pound/inch when a load of 3000 pounds is applied over an area of 250 square inches.

253.6.2.1 Performance Requirements - Standing Occupant Containment

All partitions perpendicular to the centerline of the car and not part of the passenger railcar primary structure, shall be tested for integrity and energy absorbing qualities. A load of 2100 pounds shall be applied at a point midway between the floor and the ceiling over an area of 144 square inches.

The force shall be applied in ten percent increments and the corresponding deflections measured and recorded. The force deflection curve produced shall be linear within plus or minus ten percent after the load reaches the 30 percent level. Deflection at the 30 percent load level shall not be greater than 60 percent of the full load deflection distance. The spring rate in the linear range shall not exceed 1050 pound/inch over the applied load area. A maximum deflection of twelve inches shall occur under the loading without failure.

Primary structure bulkheads and entrance doors shall be tested in a similar manner except a 3000 pound load shall be applied over an area 16 x 16 inches at a point midway between the floor and ceiling. A minimum deflection of one inch shall occur under the loading and the spring rate shall not exceed 18 pound/inch^2/inch.

253.6.3 Design Requirements - Dining Car Occupant Containment

For maximum containment, dining car tables shall be oriented in a lateral direction so that the occupants are seated facing forward or rearward. Dining car tables shall be rigidly fixed to the floor and sidewall of the car so as to contain passengers seated at them during a collision. The table shall be designed to withstand a force of 2400 pounds applied at the center of the table in a forward or rearward direction without deforming more than six inches or tearing loose. Faces of the tables shall be flush and have a minimum height of five inches. The faces shall be padded to a minimum depth of one inch.

Chairs or seats at the dining car tables shall be fixed to the floor or shall be contained by a barrier to limit movement to a maximum of six inches backwards from a neutral seating position. The seat backs shall extend to a minimum height of 34 inches above the seat reference point to contain the head and prevent whiplash. A continuous support surface shall be provided from the seat reference point to the top of the headrest.

253.6.3.1 Performance Requirements - Dining Car Containment

The dining car table shall be tested by applying a load of 2400 pounds at the center of the table in a forward or rearward direction. The table shall not deflect more than six inches without failure. Seat containment barriers, if used, shall withstand the load of two seats with a load of 12 pounds distributed over the backs of each seat. Deformation of the barrier shall not exceed six inches and failure shall not occur.

253.6.4 Design Requirements - Lavatory Occupant Containment

Restroom occupants shall be provided with containment while seated. Bulkheads, partitions, or doors shall be provided to serve as occupant containment barriers to limit the occupants travel as a result of collision. Toilets oriented in a forward or rearward direction shall have a barrier placed a maximum of 14 inches in front of the seat and immediately behind the seat. Toilets oriented in a lateral direction shall have barriers placed 14 inches on each side of the centerline of the seat. The barriers shall be designed for a maximum spring rate of 200 pound/inch for a force of 600 pounds applied over an area of 144 square inches. It shall deflect or compress a minimum of three inches under the applied load. The deflection shall not exceed twelve inches and failure shall not occur under loading.

253.6.4.1 Performance Requirements - Lavatory Occupant Containment

The lavatory barriers shall be tested by applying a load of 600 pounds to the center of the barrier over an area of 12 x 12 inches square. There shall be a minimum deflection or compression of three inches under load and the deflection shall not exceed twelve inches. Failure shall not occur during loading.

PART 254 - RAIL VEHICLE OCCUPANT IMPACT PROTECTION STANDARDS

254.1 Purpose and Scope

This standard establishes the requirements for treatment of the hazardous interior surfaces of railcar equipment, structure, and furnishings in occupied areas to minimize occupant injuries due to impact.

254.2 Application

This part applies to all locomotives, cabooses, and passenger railcars manufactured or refurbished after January 1, 1978 which are used in interstate service.

254.3 Equipment Concealment Requirements

254.3.1 Design Requirements - Non-Portable Rail Equipment Containment

Non-portable rail vehicle equipment which have corners or surfaces contoured to a radius of less than six inches or have protrusions, or surface temperature in excess of 120 degrees, shall be concealed behind flush panels. These panels shall be flat and void of external corners.

Openings in the panels for air circulation to refrigeration equipment, air conditioners, space heaters, etc., are permissible if the openings are covered with a grill. The open area of the grill shall not exceed 60-percent of the grill surface and the openings in the grill shall not exceed 0.5 inch in width.

All panels, partitions and bulkheads not primary railcar structure and which are oriented in a longitudinal direction for locomotives, cabooses and passenger cars shall be designed to withstand without failure a force of 900 pounds applied over an area of 144 square inches at the center of the panel or grill. Deformation of the panel shall not cause contact with the equipment being concealed. The panels shall be designed for a maximum spring rate of 450 pound/inch applied over an area of 144 square inches at the center of the panel.

Panels covering concealed equipment shall be secured with flush hinges and latches or shall be removable with a minimum number of flush fasteners to permit access for service or maintenance. Equipment requiring frequent access, such as a water cooler, shall be made accessible by a flush surface door in the concealment panel. Typical equipment to be concealed are:

- Heaters
- Stoves
- Fuel Tanks
- Water Tanks
- Water Coolers
- Refrigerators
- Piping
- Sinks

254.3.1.1. <u>Performance Requirements - Equipment Concealment</u>

Panels, partitions, bulkheads, grills, etc., shall be tested to determine their structural integrity and to determine their resiliancy for energy attenuation. Tests of individual panels must be representative of the actual installation in the rail vehicle. Attachments to rigid rail vehicle structure such as floor ceiling and structural bulkheads must be simulated. All bracing, attachments or other supports must be included.

The test shall consist of an impact at a velocity of 95 inch/second. Impact of a 150 pound occupant shall be simulated. The test may be performed by a vertical drop onto a horizontally oriented panel (face upward). A 150 pound sand bag with a cross sectional area not exceeding 144 square inches shall be used to simulate an occupant. Deflections shall be measured to determine spring rate stiffness and to determine if contact will take place with equipments located behind the panel. A test is considered to be unsatisfactory if the spring rate exceeds 450 pound per inch, if the deflection would cause contact with concealed equipment or if panel failure occurs.

254.4 Equipment Stowage Requirements

254.4.1 Design Requirements - Portable Equipment Stowage

Rail vehicle equipments which are portable or require emergency access, have a width in excess of six inches, have corners or surfaces contoured to a radius of less than six inches, have protrusions, or have a surface temperature in excess of 120 degrees, shall be stowed in a compartment or locker. Access to the equipment shall be through a door which shall be flush with the wall or panel in which the cabinet is mounted. The wall or panel shall have no external corners. However, when external corners are completely unavoidable they shall have a minimum radius of six inches. Hardware such as hinges, latches, handles and knobs for all compartment doors shall be flush with the door and cabinet surface.

The external surfaces of the doors and panels shall be designed to withstand an occupant impact force of 900 pounds without failure applied over a 144 square inch area at the center of the door. The door shall be designed for a maximum spring rate of 450 pound/inch. Areas of the panel backed up by a partition perpendicular to the face shall be designed for a spring rate not to exceed 1000 pound/inch.

254.4.1.1 Performance Requirements - Portable Equipment Stowage

Cabinets, lockers and stowage compartments for locomotives, cabooses and passenger railcars shall be tested for structural integrity and resiliance during simulated occupant impact. Tests shall consist of an impact at a velocity of 95 inch/sec. Impact of a 200 pound occupant shall be simulated. The test may be performed by a vertical drop onto the face of the cabinet which shall be oriented with the face upward. A 150 pound sand bag, with a cross sectional area not exceeding 144 square inches, shall be used to simulate the occupant. Deflections of the door and surfaces backed up by partitions perpendicular to the face shall be measured to determine spring rate stiffness. The tested speciment is considered to be unsatisfactory if the spring rate of the door exceeds 450 pound/inch, if the spring rate of the surface at a perpendicular partition exceeds 1000 pound/inch and if the door stop or latch fails permitting the door to spring inward.

254.4.2 Design Requirement - Luggage Stowage

Rail passenger car overhead luggage racks shall be provided with retention doors for the luggage. The doors shall be hinged and shall be flush with the edge of the rack. Doors shall not exceed 30 inches in length and shall be secured with a latch which is flush with the door surface. The doors shall be designed to withstand an interior load distributed over the surface of the door of 720 pounds. Structural failure of the door, hinge, or latch shall not occur under the applied load. Excessive deformation shall not occur which could permit the door to spring open.

Partitions or baffels shall be placed laterally along the entire length of the luggage rack at a spacing not to exceed 60 inches. The partitions shall be designed to withstand a distributed load of 1000 pounds without failure. Deformation is permissible as long as retention of the luggage would be maintained.

The floor of the luggage rack shall be designed for sufficient strength to support a load of 250 pounds at the mid-point of each or any combination of spans with no deflection exceeding .25 inch and without permanent deformation. Beams for each span shall not be located over a passengers head and it is preferable that they be located mid-way between the centerline of two passenger seats. The crown surface under the luggage rack shall be designed for a spring rate stiffness not to exceed 200 pound/inch at a point on the centerline of each passenger for an area of 25 square inches and a force of 600 pounds.

Luggage rack rail (the member at the intersection of the under-surface of the luggage rack and the inboard surface under the luggage compartment doors) shall be designed for occupant impact protection during a collision. The member shall have rounded external corner with a minimum radius of two inches and a minimum flat area of three inches high. The surface shall be padded to provide a spring rate not to exceed 20 pound/inch^2/inch. The effective thickness of the cushion shall be a minimum of one inch over the linear range.

254.4.2.1 Performance Requirements - Luggage Stowage

Luggage rack doors shall be tested for structural integrity. A load of 720 pounds shall be distributed over the inner surface of the door. The door, hinges and latches shall withstand the load without failure or excessive deformation which could lead to failure in the event of rebound load reversal.

Luggage compartment partitions shall be tested for a distributed load of 1000 pounds without failure. Deformation of the structure is acceptable if luggage retention would not be affected.

The crown surface under the luggage rack shall be tested for deformation when impacted by the head of a simulated occupant. The test shall consist of the acceleration of a 120 pound load at the underside of the luggage rack directly over the outboard passenger seat. The force shall be applied by a 150 pound weight with a five inch diameter spherical wood block attached. The block shall be accelerated into the underside of the luggage rack at a velocity of 95 inch/second. Deflections shall be measured and a spring rate determined. The spring rate shall not exceed 200 pound/inch for the impacted area.

The luggage rack rail shall be tested by applying a 300 pound load over a 25 square inch area of the padded rail. The force shall be applied in ten percent increments and the corresponding deflections measured and recorded. The force deflection curve produced shall be linear within plus or minus ten percent after the load reaches the 30 percent level. Deflection at the 30 percent load level shall not be greater than 50 percent of the full load deflection distance. The spring rate in the linear range shall not exceed 20 pound/inch^2/inch.

254.5 Equipment and Furnishings Recessing Requirements

254.5.1 Design Requirements - Recessing

Rail vehicle equipment, furnishings, controls and lighting requireing continual exposure or access for operation shall be delethalized by recessing within large, flat, structurally supportive surfaces. Such equipment or furnishings shall be recessed below the surface of the surrounding panel so that the upper most projection or surface is a minimum of two inches below the surrounding surface. The recesses shall be narrow and oriented for being bridge rather than penetrated by the body under impact. The opening for the recess shall not exceed a width of six inches across its narrowest opening. A bezel shall be provided around the opening, the edges of which shall be rounded with a radius of not less than two inches. portable equipment shall have a positive locking device to secure the equipment in the recess and it shall be designed to withstand an acceleration of 5g without tearing loose.

All interior grab rails and stanchions located below head level shall be recessed within a flush wall, panel, or appliance. The grab rail shall be provided by inserting a horizontal slot in the flush surface. The slot width shall not exceed 6.0 inches and the edges of the slot shall be rounded with a minimum radius of .75-inch. A well covering may be provided inside the slot of sufficient depth and height to permit the hand to enter the slot and grasp the lower edge of the panel below the slot as a hand rail.

Stanchions shall be flush with wall panels or partition surfaces. A minimum flat area width of six inches shall be provided on each side of the stanchion. For hand access, a maximum slot width of 4.0 inches shall be provided from the stanchion to the flat area or flush panel on both sides of the stanchion.

254.6 Equipment Covering Requirements

254.6.1 Design Requirements - Covering

Equipment not requiring continual access which have protrusions or corners having less than six-inch radius and are impractical to conceal or recess, such as a windshield wiper motor, shall be covered with a shroud or box, the corners of which shall not have less than a six-inch radius. The covers shall be made of a material that will deform a minimum of one-inch if impacted with a force of 200 pounds. Sufficient clearance shall be provided between the cover and the article being covered such that it is not contacted during the above impact condition.

Equipment requiring continual access which has protrusions or corners having less than six-inch radius and is impractical to conceal or recess, such as control handles, shall be shielded by a guard. The guard shall present an impact surface above and below or to the sides of the article being shield. A slot having a maximum width of six inches shall be made in the impact surface for the article being shielded. The impact surface shall be as flat as practical and the edges around the slot shall be rounded with a minimum radius of two inches. The guard shall be a minimum of two inches above the object being shielded. The guard shall be designed to withstand an impact force of 1000 pounds without failure and shall not permit contact, during deformation, with the equipment being guarded. The guard shall be designed for a spring rate of 300 pound/inch for a 600 pound force over an area of 36 square inches.

254.6.2 Performance Requirements - Equipment Covering

External covers extending above a surface shall be tested by applying a load of 200 pounds by a flat surfaced load applicator. The cover shall deform a minimum of one inch under the applied load. Deformation in excess of one inch shall not cause contact with the object being covered.

Covers with slots for access shall be tested by applying a load of 600 pounds to a 36 square inch area to the surfaces on each side of the slotted area. The guard shall deform a minimum of one inch under the applied load. Deformation in excess of one inch shall not cause contact with the object being covered.

PART 255 - RAILCAR SEATING SYSTEM STANDARDS

255.1 Purpose and Scope

This part prescribes crashworthy seating requirements for locomotive, caboose, and passenger railcars.

255.2 Application

This part applies to all seats used on locomotives, cabooses, and passenger railcars manufactured or refurbished after January 1, 1978 which are used in interstate service.

255.3 Definition

Seat Reference Point (SRP) - The point of intersection between the forward surface of the seat back cushion and the top surface of the seat pan cushion.

255.4 Rail Vehicle Seating Requirements

Crashworthy rail vehicle seats shall be designed to provide the maximum occupant collision protection for the general population under forward, sideward, and rearward accelerations.

255.4.1 Design Requirements - Rail Vehicle Seats

a. Seat Backs - Seat backs shall extend a minimum of 34 inches above the seat reference point to provide upper torso and head support during rearward accelerations. The back shall be continuous. Separate or removable headrests shall not be used. The headrest area of the seat back shall be in the same plane as the seat back or shall extend forward of the seat back plane up to a maximum of two inches. Abrupt transitions from the plane of the headrest and seat back surface shall be avoided. Extensive contouring of seat backs shall be avoided so as to provide a more even distribution of rearward loading for small as well as large occupants.

Continuous load supporting membranes shall be used in seat backs rather than intermittent members. Use of spreader bars or ribs shall not be used which can produce concentrated loading on the occupant during rearward acceleration or forward acceleration into seat backs in front of occupants.

The rear of seat backs on seats used in tandem shall be sufficiently padded to prevent injury to passengers who are thrown into the backs of seats. The top of the seat back which could be struck by the face shall be covered with a soft cushion of two densities. The outer layer shall be the softer density having a maximum spring rate of five pound/inch^2/inch and a minimum thickness of 1.0 inch. The under surface shall have a maximum spring rate of ten pound/inch^2/inch. The padding shall be designed for an applied load of 50 pounds over a 15 sqaure inch area.

The area of the seat back at the knee level, 20 inches above the floor, shall be kept clear of rigid, non-yielding members. It shall be designed for a maximum spring rate of 38 pound/inch^2/inch for an applied load of 600 pounds over an area of eight square inches. Seat backs shall be void of rigid hand holds, ticket holders, headrest towel clips, foldout trays, etc.

b. <u>Rear Seat Skirt</u> - When seats are used in tandem, the rear surface below the seat cushion of the leading seat shall be partially enclosed with a skirt to avoid leg entrapment. The skirt shall be angled forward 30° from vertical to allow maximum leg room. It shall clear the floor by six inches to provide sufficient space for the foot to extend beneath the skirt. The skirt surface adjacent to the instep shall be rounded and padded to a minimum thickness of 0.5 inches.

c. Lateral Restraints - All seats in locomotive, caboose, and passenger rail vehicles, except dining car seats and those seats equipped with a shoulder harness, shall have a shoulder restraint wings located beside the shoulder. Wings shall be attached to the seat back on both sides of single and multiple occupancy seats. A single wing shall be provided between each occupant on multiple occupancy seats. The wing shall have a minimum width and height of eight inches and the top shall be 24 inches above the seat reference point. The radius of the forward upper corner shall be a minimum of three inches. All exposed surfaces shall be covered with a minimum of one inch of padding material.

d. Armrests - All seats in locomotive, caboose, and passenger rail vehicles, except dining car seats and those seats equipped with a full restraint system shall have an armrest or a padded surface in the position of the armrest. A flat continuous load bearing padded surface shall extend from the top of the armrest to the surface of the seat cushion. A minimum of one inch of padding material shall be used to cover all exposed surfaces of the armrest.

e. Seat Locking and Adjustment - Single or double occupancy walkover or reversible seats shall be provided with a positive locking device to prevent seat back displacement or seat disorientation during collision. The locking device shall withstand collision loads applied in any of the three axis. Locks shall not be provided to prevent swiveling of single occupancy swivel passenger seats. The locking device shall be designed to withstand forward loads of 1200 pounds applied to single seats in locomotives and passenger railcars, 2400 pounds applied to double occupancy passenger seats and 3000 pounds applied to caboose seats.

Seats which are vertically adjustable or adjustable horizontally on tracks shall be provided with adequate stops and positive locks so as not to become disengaged or displaced as a result of accelerations in any of the three axis. Locks on the swivel adjustment of swiveling trainmen seats is optional.

f. Face-to-Face Seating - Although face-to-face seating has been a practice with both walk-over and rotatable passenger seats, the practice shall be eliminated. Use of such arrangements nullify the crashworthy containment features of one direction seat facing. Provisions shall be made to prevent reversal of seats without use of a special tool or key by railroad personnel only.

g. Passenger Swivel Seats - The rotational axis of individual swivel passenger seats shall be at least twelve inches ahead of the seat reference point to permit automatic rotation of the seat to a favorable containment position during collisions. Detail design requirements for seat back design, armrests, lateral shoulder restraints and leg entrapment skirts shall be the same as for double occupancy passenger seats. Load requirements are the same as for one side of a double occupancy seat.

h. <u>Seat Loading</u> - All locomotive and passenger car seats shall be designed to withstand the load of a 200 pound occupant thrust rearward into the seat back at 6g, or 1200 pounds, without failure or deformation to the extent to negate containment. Tandem seats shall also withstand loads of 600 pounds applied in a forward direction to the top area of the seat back and loads of 600 pounds applied simultaneously to a point on the seat back 20 inches above the floor. This loading simulates an occupant behind the seat being thrust into the seat back and contacting it with the knees and upper torso. Arm rests and shoulder restraint wings shall be designed to withstand distributed loads of 400 pounds applied to each simultaneously in a lateral direction. Multiple-occupancy seats shall be designed to withstand the above loads applied to each section of the seat simultaneously. Carry-through structure and floor attachments shall withstand the total loading without failure, without deformation to the extent to negate containment, or unlatching of the seat rotation locking device.

Locomotive seat backs with provisions for shoulder straps shall be designed to withstand a load of 1000 pounds applied at a single or double shoulder strap retractor reel attachment point and to the seat back frame for the forward load component from straps that pass over the frame. Lap belt attachments shall be designed to withstand a 500 pound load applied simultaneously to attachments on each side of the seat pan. The seat shall be designed to withstand simultaneous restraint system loading of seat back and seat pan.

Caboose trainmen seats shall be designed to the same lateral loading conditions as locomotive and passenger seats. Longitudinal loading requirements are higher due to the higher accelerations experienced in caboose collisions and slack action. The seat shall be designed for 15g or 3000 pounds applied rearward to the seat back. Tandem seat configurations shall be designed to withstand loads in a forward direction of 1500 pounds applied simultaneously to the top of the seat back and knee area of the seat back 20 inches above the floor. Seat backs with shoulder strap provisions shall be designed to withstand a load of 1500 pounds for a single or double strap retractor reel attachment. Design shall be for simultaneous application of an 800 pound load applied to lap belt attachments on each side of the seat pan. The seat shall be designed to withstand simultaneous retraint system loading of seat back and seat pan.

255.4.2 <u>Performance Requirements Rail Vehicle Seats</u>

Rail vehicle seats shall be tested for structural strength and for the energy absorbing properties for the various areas of the seat as follows:

a. <u>Seat Back Top</u> - The top rear surface of all seats that are arranged in tandem shall be tested for spring rate of the padding. A flat surfaced load applicator shall be used which has an area of 15 square inches. A force of 300 pounds shall be applied on the centerline of the seat back top. The force shall be applied in ten percent increments and the corresponding deflections measured and recorded. The force deflection curve produced shall be linear within plus or minus ten percent after the load reaches the 30 percent level. Deflection at the 30 percent load level shall not be greater than 50 percent of the full load deflection distance. The spring rate in the linear range shall not exceed ten pound/inch^2/inch.

b. Seat Back Rear - The rear of the seat back shall be tested for spring rate. A load applicator with two flat 2.5 inch diameter bearing plates to simulate an occupants knees shall be used. The centerlines of the circular plates shall be ten inches apart. A load of 300 pounds shall be applied to each plate at a point on the rear of the seat back 20 inches above the floor.

The force shall be applied in ten percent increments and the corresponding deflections measured and recorded. The force deflection curve produced shall be linear within plus or minus ten percent after the load reaches the 30 percent level. Deflection at the 30 percent load level shall not be greater than 60 percent of the full load deflection distance. The spring rate in the linear range shall not exceed 38 pound/inch^2/inch.

c. Locomotive and Passenger Seat Backs - Seat backs of locomotive and passenger seats shall be tested for structural integrity. A distributed load of 1200 pounds shall be applied in a rearward direction. The seat back shall withstand the load without failure and the deflection measured at the top of the seat shall not exceed six inches. Seat support base and floor attachments shall also withstand the loading without failure. The test shall be repeated under the same conditions and limitations with a load applied to the rear of the seat back in a forward direction.

d. Caboose Seat Backs - Seat backs of caboose seats shall be tested in the same manner and with the same limitations as locomotive and passenger seats except the load applied shall be 3000 pounds.

e. Arm Rests and Wings - Arm rest and shoulder restraint wings of all rail vehicle seats shall be tested for integrity. A distributed load of 400 pounds shall be applied to the arm rest for each occupant simultaneously in the same lateral direction. A simultaneous distributed load shall be applied to the shoulder wings for each occupant in the same lateral direction. Deflection shall not exceed 4.0 inches at the extremities and failure shall not occur. Loading shall not cause unlatching of the seat or disorientation of latched seats. Free swiveling seats shall be fixed for the load application test.

f. Restraint System Attachments - Shoulder strap and lap belt attachments to seats provided with restraint systems shall be tested for integrity. A body block simulating the torso of a 95th percentile male occupant shall be used to apply load to the attachment fittings as prescribed in Section 256 Restraint System Design Requirements. The seat structure and attachment points shall withstand the load without failure and without deflection of the seat exceeding three inches measured at the top of the seat back.

PART 256 - TRAINMEN SEATBELT STANDARDS

256.1 Purpose and Scope

This part prescribes requirements for seat belt assemblies when used, to restrain rail vehicle occupants during train accelerations and collisions.

256.2 Application

This part applies to all locomotives and cabooses manufactured or retrofitted after January 1, 1978 which are used in interstate service. Application requirements as to type of seat belt for the various rail vehicles and seating environments are prescribed in Part 253.

256.3 Definitions

Seat Belt Assembly - Seat belt assembly means any strap, webbing, or similar device, including all necessary buckles and other fasteners and all installation hardware, designed to secure a person in a rail vehicle in order to mitigate the results of any accident. for installing such seat belt assembly in a rail vehicle.

Pelvic Restraint - Pelvic restraint means a seat belt assembly or portion thereof intended to restrain movement of the pelvis.

Upper Torso Restraint - Upper torso restraint means a portion of that seat belt assembly intended to restrain movement of the chest and shoulder regions.

Hardware - Hardware means any metal or rigid plastic part of a seat belt assembly.

Buckle - Buckle means a quick release connector which is used to fasten a person in a seat belt assembly.

Emergency-Locking Retractor - Emergency-locking retractor means a device for storing part or all of the webbing in a seat belt assembly and incorporates adjustment hardware by means of a locking mechanism that is activated by rail vehicle acceleration, webbing movement relative to the vehicle, or other automatic action during an emergency and is capable when locked to withstanding restraint forces.

Type 1 Seat Belt Assembly - A lap belt for pelvic restraint.

Type 2 Seat Belt Assembly - A combination of pelvic and upper torso restraint system including lap belt and shoulder harness.

256.4 Design Requirements

a. Single Occupancy - A seat belt assembly shall be designed for use by one, and only one, person at any one time.

b. Pelvic Restraint - A seat belt assembly shall provide pelvic restraint whether or not upper torso restraint is provided, and the pelvic restraint shall be designed to remain on the pelvis under all conditions, including collision or rollover of the rail vehicle. Pelvic restraint of a Type 2 seat belt assembly that can be used without upper torso restraint shall comply with requirement for Type 1 seat belt assembly. The pelvic restraint system shall be attached to the seat pan at a point 2.5 ±0.5 inches forward of the seat reference point.

c. Upper Torso Restraint - A Type 2 seat belt assembly shall provide upper torso restraint in the forward and lateral directions. An upper torso restraint shall be designed to minimize vertical forces on the shoulders and spine. The shoulder straps shall be attached or pass over the seat back support at a point 26 ±0.5 inches above the seat reference point. The restraint system shall be comfortable, light in weight, and easy for the occupant to put on and remove. When installed, the upper torso restraint shall not inhibit motions for the normal performance of trainman's duties. Hardware for upper torso restraint shall be so designed and located in the seat belt assembly that the possibility of injury to the occupant is minimized.

d. Emergency-Locking Retractor - An emergency-locking retractor shall be provided for the Type 2 seat belt shoulder harness and shall perform as follows:

1. Shall lock before the webbing extends one inch when the retractor is subjected to an acceleration of 0.7g.

2. Shall not lock, if the retractor is sensitive to webbing withdrawal, when the retractor is subjected to an acceleration of 0.3g or less.

3. Shall exert a retractive force of not less than 0.2 pound and not more than 1.1 pounds under zero acceleration when attached only to an upper torso restraint.

4. Shall exert a retractive force of not less than 0.2 pound and not more than 1.5 pounds under zero acceleration when attached to a strap or webbing that restrains both the upper torso and the pelvis.

e. Buckle - The seat belt assembly shall be provided with a single buckle readily accessible to the occupant to permit his easy and rapid removal from the assembly. The buckle shall be a metal-to-metal cam release type having a tongue insertion port on one side for attaching the lap belt half and shall be fixed on the other side to the other lap belt half. Similar insertion ports shall be provided on the top of the buckle for tongue insertion from the shoulder harness when a type 2 system is used. Each tongue shall be capable of being inserted in the buckle independently without disturbing or releasing the other attachments. A positive locking device shall be incorporated in the buckle to prevent unintentional release of any component of the seat belt assembly. This device shall give positive indication of any unlocked condition. The intentional buckle shall be capable of being operated with only one finger of either hand while tension equal to the occupant's weight is supported by the system. The force required to release the system with only one finger shall be not less than 15 pounds and not more than 25 pounds.

A lift lever type release shall be used and shall eject lap belt and shoulder harness fittings simultaneously. An adjustment feature shall be incorporated in the lap belt tongue fitting on Type 1 seat belts to permit tightening the assembly. An additional adjustment feature shall be incorporated in the buckle for the other half of the lap belt on Type 2 seat belts with double shoulder strap buckle attachments to permit centering the buckle. The buckle and attaching hardware shall be designed to withstand a load of 3000 pounds without failure or permanent deformation.

f. Webbing

1. Dimensions - The width of the webbing in a Type 1 or Type 2 seat belt assembly shall be not less than 1.8 inches. Thickness of the webbing shall be not less than 0.065 inch for lap belts and 0.045 for shoulder straps.

2. Breaking Strength - The webbing used in a Type 1 or Type 2 seat belt assembly shall have a breaking strength of not less than 6000 pounds.

3. Elongation - The webbing used in a Type 1 or Type 2 seat belt assembly shall not have an elongation of more than seven percent under a tension load of 2000 pounds.

g. Hardware

1. Corrosion Resistance - All seat belt hardware shall be fabricated from corrosion-resistant materials.

2. Surface Finish - All hardware parts which contact under normal usage a person, clothing, or webbing shall be free from burrs and sharp edges. Fittings in contact with the straps shall have a maximum surface roughness of RMS-32 to prevent fraying of the strap due to frequent movement over the metal.

h. Assembly

1. Adjustment - The seat belt assembly shall be capable of adjustment to fit occupants whose dimensions and weight range from those of a 5th-percentile adult male to those of a 95th-percentile adult male.

2. Marking - Each seat belt assembly shall be permanently and legibly marked or labeled with year of manufacture, model, and name or trademark of manufacturer or distributor.

3. Webbing Assembly - The ends of webbing in a seat belt assembly shall be protected or treated to prevent raveling. The end of webbing in a seat belt assembly having adjustment fittings that are used by the occupant to adjust the size of the assembly shall not pull out of the adjustment hardware at maximum size adjustment.

256.5 Performance Requirements - Restraint Systems

256.5.1 Seat Belt Assembly Performance

The seat belt assembly including webbing and all hardware components shall withstand without permanent deformation or adjuster slippage the following loading tests:

a. Type 1 seat belt system attached at the anchor fittings and loaded in tension to 2000 pounds.

b. Type 2 seat belt system with retractor and lap belt anchor fittings attached to a rigid structure in a manner to simulate installation on a trainman seat and loaded by a body block in a forward direction to 3000 pounds at a point on the centerline of the body block ten inches abo e the seat surface.

c. The Type 1 and Type 2 systems shall withstand the loads without failure, permanent deformation or webbing slippage greater than 0.125 inch. A maximum elongation of seven percent is permissible in the webbing measured from a point after an initial load of 100 pounds is applied, to the point when full load is applied.

PART 257 - RAIL VEHICLE WINDOW STANDARDS

257.1 Purpose and Scope

This part prescribes requirements for window glazing materials, window retention, impact forces and emergency exit provisions for rail vehicle windows.

The purpose of this standard is to minimize the probability of foreign objects entering the rail vehicle through the glazing material to reduce injuries resulting from occupant impact to glazing surfaces, to minimize the possibility of occupants being thrown through the vehicle windows in collisions, and to provide glazing removal provisions for emergency egress.

257.2 Application

This part applies to all locomotives, cabooses, and passenger railcars manufactured or refurbished after January 1, 1978 which are used in interstate service.

257.3 Window Glazing - Side Windows

a. General Requirements - Glazing materials for use in rail vehicles, except as otherwise provided in this standard, shall conform to the American National Standard "Safety Code for Safety Glazing Materials for Glazing Motor Vehicles Operating on Land Highways," Z26.1-1966, July 15, 1966, as supplemented by Z26.1a-1969, March 7, 1969.

b. Glazing Materials - Side window glazing for all rail vehicles shall be of laminated annealed safety glass using two pieces of glass bonded with a plasticized poly-vinyl but nal resin membrane which is resistant to ultra-violet and visible light and heat. The bond between the sheets of laminated glass and the membrane shall be of such quality that when the glass is broken by shock, by twisting or by direct impact, there will be no material separation b tween laminations.

c. Strength - Window glazing strength shall be determined to permit deformation for the minimization of occupant injury due to impact, to provide retention of occupant preventing ejection through the window, to minimize the probability of foreign object penetration from the outside and for wind pressure and shock. Side windows of all rail vehicles shall be designed for air pressures experienced at the top speed of the rail vehicle and for shock due to passing other trains and shock due to entering and exiting tunnels. The glass shall be designed to withstand without penetration from the out side, the impact of objects of the size, density, weight and hardness of a standard baseball impacting at 75 feet/second. The glass shall have a spring rate not to exceed 450 pound/inch over an impact area of 19 square inches. It shall retain an occupant impacting from within at a velocity of 150 inch/second. Deformation of the glass or membrane is acceptable as long as the continuity of the membrane is not broken and ejection through the glass is prevented.

257.4 Window Glazing - Forward Windows

Window glazing material used in forward-facing windows in occupied areas of locomotives and cabooses serving as windshields and which are not normally protected by other elements in a consist shall, unless otherwise specified in this standard, have minimum properties as determined by tests listed in Item 1, Table 1 USAS Z 6.1-1966. These windows need not meet the human impact, no injury requirements of Part 257.3. Window glazing for windows facing in a rearward direction of locomotives and cabooses capable of use in continuous multi-directional operation shall meet the requirements for forward-facing windows.

Forward-facing unprotected windows shall be designed to prevent penetration by a 25 pound object of the density of concrete impacting the glass at a velocity of 88 feet/second. This requirement will suffice for the pressure and shock requirements. Deformation of the glass or membrane is acceptable as long as the continuity of the membrane is not broken and the glass/membrane is retained in the window sash. The maximum deformation shall be 18 inches. Spall shall be contained to within 28 inches of the original plane of the glass. Partial vision through the glass shall be maintained after impact.

All other forward-facing windows in rail vehicles which are normally protected by other rail vehicles in the consist shall meet the requirements of side-facing windows as specified in Section 257.3

257.5 Window Glazing - Emergency Egress

A minimum of one emergency egress window shall be provided in each side of each occupiable rail vehicle for every 15 person capacity of the rail vehicle. The window sash or glazing may be completely removable, hinged or sliding and shall provide an opening sufficient to permit egress by a 98th percentile male occupant. Distortion of the window frame shall not impede window opening or removal. Operation of the window for emergency egress shall be simple and capable of operation by a 5th percentile woman. Operation procedures shall be clearly marked on the release device which shall be engraved and filled with luminescent material.

257.6 Window Glazing - Interior Windows

Glass when used in passenger railcar interior doors, lavatories and partitions shall be designed primarily for the prevention of injury to occupants during impact. The glass shall be designed with a spring rate not exceeding 450 pound/inch over an area of 19 square inches. A membrane should be used in the glass to retain the integrity of the glass as a barrier in preventing occupant ejection through the glass. Maximum retention of shattered glass granules should be provided for.

257.7 Performance Requirements - Window Glazing

Window glazing used in rail vehicles shall be tested with the mounting sash section window frame and retaining provisions. The assembly shall be mounted in a rigid structure which will not deflect or deform under the impact test load.

a. Side facing windows shall be tested by impacting at the center with a six inch diameter spherical wood block weighted to 150 pounds. The block shall be accelerated and impact the glass at 150 inch/second. Deflections shall be recorded and spring rate determined. The glass and/or membrane shall deflect a minimum of four inches or the spring rate shall not exceed 450 pound/ inch over the linear range of the force deflection curve. Retention of the glass panel in the frame shall be maintained and there shall be no penetration of the impactor through the membrane.

b. Forward-facing windows shall be tested by impacting at the center with a spherical concrete ball weighing 25 pounds. The ball shall be accelerated and impact the glass at 88 feet/second. Retention of the glass in the frame shall be maintained and there shall be no penetration of the impactor through the membrane. A maximum deflection of 18 inches is permitted. Presence of spall shall be observed and shall not have been projected more than 28 inches behind the original plane of the glass. The glass shall be checked for vision after impact and the minimum of 20 percent vision area shall remain.

PART 258 - FLAMMABILITY OF INTERIOR MATERIALS

258.1 Purpose and Scope

This standard specifies burn resistance requirements for materials used in the occupant compartments of rail vehicles.

The purpose of this standard is to minimize injuries and fatalities of rail vehicle occupants caused by vehicle fires, especially those originating in the interior of the vehicle.

258.2 Application

This part applies to all locomotives, cabooses, and passenger railcars manufactured or refurbished after January 1, 1978 which are used in interstate service. This standard includes materials used in the following applications:

a. Floor, wall, and ceiling covering
b. Floor coatings
c. Sound-absorbing materials
d. Water tank coatings
e. Seat cushions, coverings, and arm and headrests
f. Restraint systems
g. Bulkhead, counter, partition, cabinet, panel, shelving, and luggage rack materials and coatings
h. Curtains, shades, and sun visors
i. Mattresses, bedding, and covers
j. Energy-absorbing materials and padding
k. Paints and finishing coatings

258.3 Non-Flammability Requirements

All non-metallic materials selected for use in interior of occupiable compartments of rail vehicles shall have flame retardant and non-toxic properties. The material shall not burn, or transmit a flame front across its surface, at a rate of more than four inches per minute in a no-draft environment. However, if a material stops burning before it has burned for 60 seconds from the start of timing, and has not burned more than two inches from the point where timing was started, it shall be considered to meet this requirement. The portions of material components that shall meet these requirements are as follows:

a. The surface material taken separately if it is not bonded, sewed or mechanically attached to underlying material.

b. A composite consisting of the surface material bonded, sewed or mechanically attached to underlying material, if such a composite is used in the component.

c. Padding and cushioning materials taken separately, if those materials are not bonded, sewed or mechanically attached to surface materials.

258.3.1 Performance Requirements - Non-Flammability

Non-metalic materials used in rail vehicles shall be tested in accordance with and shall meet the following requirements.

1. Seat cushions, energy absorption padding and thermal and acoustical foams shall be capable of passing the ASTM E 162-67 Radiant Panel Test with a flame propagation index not exceeding 25. Additional provisions are as follows: a) there shall be no flaming running or dripping, b) wire mesh screening shall be used (as per Section 4.9.2), c) a six inch long pilot flame (burner tip situated 1-1/4

inch beyond the frame to prevent extinguishment), d) aluminum foil shall be used to wrap around the back and sides of the specimen. Furthermore, the fire-resistant properties of the foam shall be demonstrated to be permanent through multiple dry cleanings.

2. Wall and ceiling coverings shall be capable of passing the ASTM E 162-67 Radiant Panel Test with a flame propagation index not exceeding 35, with the additional provision that there shall be no flaming drippings.

3. Upholstery materials shall be tested by FAA Regulation 25.853 vertical test, Appendix F(b), with the following modifications: a) the average flame time after removal of the flame source may not exceed ten seconds, b) burn length shall not exceed six inches, c) flaming drippings shall not be allowed, d) the samples of material shall, after 15 minutes immersion in water and thorough drying, still conform to this test, e) multiple dry cleaning shall not affect flame retardancy.

4. Carpeting shall be tested with its padding, if latter is to be used, and shall be capable of passing the ASTM E 162-67 Radiant Panel Test with a flame propagation index not exceeding 75.

5. Plastic windows and lighting diffusers shall be capable of passing the ASTM E 162-67 Radiant Panel Test with a flame propagation index not exceeding 100.

6. Flooring shall be capable of passing the requirements of ASTM E 119 when tested for 15 minutes exposure to 1400°F maximum.

7. Elastomers shall be capable of passing the requirements of ASTM C542-71a, with the added requirement that flaming drippings shall not be allowed.

8. Electrical insulation. Wires for control, auxiliary circuits, speaker, public address, intercom system and the like shall be tested according to I.P.C.E.A. S-19-81, paragraph 6.19.6 or Underwriters Laboratory Standard 62. The exception to these standard procedures is that the 15 second flame exposure and rest cycle is changed to read as follows: In any case, the flame is not to be re-applied until any flaming which is caused by the previous application ceases of its own accord, even though the time interval between applications may exceed 15 seconds.

   High voltage cable shall be tested according to the IEEE Standard 383-1974. A further provision of this test is that circuit integrity continue for five minutes after the start of the test.

258.4 Non-Toxic Requirements

All non-metallic materials selected for use in interiors of occupiable compartments of rail vehicles shall not give off toxic vapors when burned or subjected to high temperatures. Refer to the Material Data Bank Catalog DOT-TSC-926-3 for non-toxic materials when selecting materials.

258.5 Smoke Emission Requirements

All combustible materials shall meet the smoke emission requirements as follows:

a. For upholstery, air ducting, thermal insulation and insulation covering, the D_s may not exceed 100 within four minutes after start of the test.

b. For all other materials, with the exception of foam seat cushioning and electrical insulation, the D_s may not exceed 100 within 90 seconds after the start of the test, and may not exceed 200 within four minutes after the start of the test.

258.5.1 Performance Requirements - Smoke Emission

All combustible material shall be tested for smoke emission in accordance with the National Bureau of Standards Technical Note 708, "Interlaboratory Evaluation of Smoke Density Chamber", December 1971, Appendix II, "Test Method of Measuring the Smoke Generation of Solid Materials," dated September 1971, or NFPA No. 258-T, "Smoke Generated by Solid Materials" (1974). The optical density, D_s, in both flaming and non-flaming modes shall be determined by the tests.

APPENDIX A
HUMAN TOLERANCE TO IMPACT

Human tolerance is difficult to establish because of the obvious impracticability of subjecting humans to impact at serious injury levels. The main classifications of human tolerance are:

1. Voluntary
2. Injury threshold
3. Minor injury
4. Severe injury

The voluntary tolerance level is established by subjecting human volunteers to the environment being studied. Generally, the approach is to subject the volunteers to a very low level exposure with the exposure severity increased until the volunteer refuses to go further for fear of injury. In a few cases volunteers have been injured, but in general, the voluntary level is well below the injury level. Nevertheless, the voluntary tolerance threshold is beneficial since it is the only tolerance value that is based upon results from carefully controlled human experiments where the physical parameters are known accurately.

The injury threshold is defined as the impact conditions at or just below the point at which injury occurs. The injury threshold has been achieved or exceeded in some volunteer experiments since there have been some minor injuries. However, the general voluntary levels are well below the injury threshold.

Minor injury is usually defined as injury resulting in bruises, abrasions, contusions, or other minor recoverable injuries that are acceptable to the occupant. The minor injury threshold has been reached by some volunteers and in general is probably acceptable in the design of intercity rail vehicles. In establishing the minor injury category, it is necessary to realize that what might be considered a minor injury, insofar as danger to life is concerned, might not be considered a minor injury in the general sense of an injury that is acceptable to an individual. In this respect a fractured rib is considered to be a minor injury form a life-threatening standpoint, while the same fractured rib will generally not be considered a minor injury by the riding public.

Severe injuries include serious injuries up to fatal injuries. These often require surgical intervention and long recovery times. The severe injury level is obviously not acceptable for the tolerance level for intercity railcars.

When establishing human tolerance levels, the resistance of the "average" individual is the basis for the tolerance level. It has been established[1, 2] that age, sex, and physical conditions are only a few of the variables that effect the tolerance of humans to impact. Age is of particular importance with the degree of injury for a given impact increasing markedly at the higher age level. In some exposures the tolerance is low for young people. Burdi and Huelke[3] point out the differences in anatomy between children and adults. With the variation from individual to individual in the ability to sustain impact without injury, it should be realized that in any given environment those least able to withstand the impact will be injured at a low severity of collision, while the more resistant individual will sustain no injury whatsoever under the same conditions.

Methods of establishing human tolerance to impact range from the exposure of human volunteers to the environment in question to reproducing accidents in which the collision severity and degree of injury are known. For some types of injuries, the volunteer program can be extended to more severe exposures by substituting unembalmed human cadavers to the impact environment. Bruising, bone fractures, and internal injuries have all been observed in cadavers with results that are similar to those observed in collisions.

Before tolerance levels can be specified, it is necessary to have a uniform method of describing injuries. The Abbreviated Injury Scale (AIS) has been established for use in automobile injury studies[4] and is recommended for application to railcar injuries in order to maintain uniformity and to permit the results from the more numerous automobile injuries to be applied to railcar design. The nine injury categories of

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1. Patrick, L.M., Bohlin, N., and Anderson, A., "Three-Point Harness Accident and Laboratory Data Comparison", SAE Paper No. 741181.

2. Yamada, H. (Edited by Evans), "Strength of Biological Materials", Williams and Wilkins, 1970.

3. Burdi, A.R., and Huelke, D.F., "Infants and Children in the Adult World of Automobile Safety Design: Pediatric and Anatomical Considerations for Design of Child Restraints", Journal of Biomechanics.

4. Abbreviated Injury Scale: Zero to nine (fatal)

the AIS cover the range from essentially zero injuries to fatals. For railcar application it may be desirable to use only the first three AIS categories and to enlarge on the definitions of the injuries within each of these categories. It is recommended that the AIS-3 level be the maximum acceptable injury with a design goal of AIS-0 injury for all rail occupants in collisions up to the 20 mph severity.

Injury criteria which have been established and are in general use, including those of Motor Vehicle Safety Standards (MVSS) 208[5], are:

1. The Head Injury Criterion (HIC)
2. The Gadd Severity Index (GSI)
3. The 80-g, three-millisecond exclusion parameter for head impact (i.e. does not exceed 80g continuously for more than 3 milliseconds).
4. The 60-g three-millisecond exclusion chest impact criterion.
5. The 1700-pound femur load for dummy knee impact.
6. Torque at the occipital condyles.

The injury criteria of MVSS 208 are not all inclusive. Therefore, additional injury criteria will be suggested for the specific injury conditions. (A list of terms pertaining to injury is presented in Table A-1).

HEAD IMPACT

- Injury Type: brain injury, skull fracture, and/or scalp laceration
- Human Tolerance: HIC = 1000

Head injury is considered to be injury to the skull, scalp, and/or brain and does not include the facial injury.

Melvin and Evans[6] summarized the fracture forces from different investigators with a skull fracture range of 500 to

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5. Title 49, Code of Federal Regulations, Part 571 - Federal Motor Vehicle Safety Standards, National Highway Traffic Safety Administration, Department of Transportation, Washington, D.C.

6. Melvin, J.W., and Evans, F.G., "A Strain Energy Approach to the Mechanics of Skull Fracture," Proceedings of the Fifteenth Stapp Car Crash Conference, November, 1971, SAE No. 710871.

TABLE A-1. INJURY TERMS

AIS	Abbreviated Injury Scale; zero to nine (fatal)
AP Mandible	Anterior posterior on jam
Basil	Base
Caudal	Posteriorly (opposed to cephalad)
Caudal Cephalad Direction	Loads transmitted vertically through the spine
Caudal Cephalad Loading	Vertically along the spine
Cephalad	Anterior part of body (opposed to caudal)
Cervical Vertebra	The seven vertebra in the neck region
Coccyx	A small bone at the lower end of the vertebral column
Condyles	Ball and socket joints
Contusion	Injury in which skin is not broken
Distal	Terminal
Dorsal	Of, on or near the back
Femur	Thigh bone
Fibula	Leg calf bone
Frontal Bone	Convex front portion of skull
GSI	Gadd Severity Index
HIC	Head Injury Criteria
Hyperextension	Extreme rearward rotation of head
Hyperflexion	Head striking chest
Ilium	Upper portion of the hip bone
Intervertebral Discs	Elastic discs interposed between the centra of adjoining vertebrae
Ischia	Lower portion of the hip bone
Laceration	Jaggedly torn flesh
Lateral Mandible	Sideways on jaw
Ligaments	Tissue connecting the bones
Lumbar	Lower part of the back
Mandible	The jaw
Maxilla	Jaw bone
Occipital	Posterior part of the skull bone
Patella	The knee cap
Pelvis	A basin like cavity formed by a ring of bones supporting the spine
Sternum	The breastbone
Tibia	The lower leg (shin) bone
Thorax	The chest (between the neck and abdomen)
Torso	The trunk of the human body
Vertebra	The articulating bones of the spinal column
Viscera	The inner parts of the body especially of the thorax and abdomen
Zygoma	The anterior portion of the upper jaw bone

2200 pounds depending upon the impact conditions. A small area of impact resulted in the 500-pound fracture level while a 2200-pound fracture force resulted from a large area impact without padding. A flat surface impact to the frontal bone with approximately 3/4 inch of padding shows no fracture at forces up to 2640 pounds in another study.[14]

Nahum[7] quotes a minimum fracture force of 900 pounds and an average of 1100 pounds from impact to the frontal bone with a one-square-inch impactor.

With the human volunteer runs on the Holloman sled with the GM air cushion, Smith et al[8] reached a maximum HIC of 380 and a maximum acceleration of 71 g's in the head at a 30 mph barrier equivalent impact. These did not result in injury, and did have a greater stopping distance than feasible from a seat back impact.

Hodgson et al[9] reported on probably the most significant study with regard to impacting a grab rail. He impacted cadavers with cylindrical steel unpadded impactors of 5/16-inch radius and one inch radius. The average fracture level was 1250 pounds with a range of 700 to 1730 pounds.

A well-designed helmet provides an excellent example of the impact attenuation that can be achieved under ideal conditions with approximately 0.8-inch deceleration distance available. A helmet impact at 12 to 16 mph to a rigid surface often does not result in head injury. At an impact of 12 mph a helmeted head does not exceed 80 g's if the helmet is adequately designed.

For a seat back designed with a three-inch decelerating distance from a head impact of 20 mph, the maximum head acceleration should not exceed 80 g's and the HIC will be approximately 400. These values are extremely conservative and should cause no brain injury or skull fracture. Adequate padding to distribute the force will eliminate soft tissue or scalp injury with the exception, perhaps, of a bruise.

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7. Nahum, A.M., Gatts, J.D., Gadd, C.W., and Danforth, J., "Impact Tolerance of the Skull and Face", Proceedings of the Twelfth Stapp Car Crash Conference, October, 1968, SAE Paper No. 680785.

8. Smith, G.R., Gulash, E.C., and Baker, R.G., "Human Volunteer and Anthropomorphic Dummy Tests of General Motors Driver Air Cushion System", 3rd International Conference on Occupant Protection, Troy, Michigan, July, 1974, SAE Paper No. 740578.

9. Hodgson, V.R., Brinn, J., Thomas, L.M., and Greenberg, S.W., "Fracture Behavior of the Skull Frontal Bone Against Cylindrical Surfaces", Proceedings of the Fourteenth Stapp Car Crash Conference, November, 1970, SAE Paper No. 700909.

FACE IMPACTS

- Injury Type: Facial bone fracture, soft tissue injury and eye injury

- Human Tolerance: Zygomatic arch 200 pounds minimum, 648 pounds maximum; maxilla, 150 pounds minimum, lateral mandible 200 pounds, AP mandible 400 pounds.

Facial bone fractures are sensitive to the area and hardness of the impactor. The minimum force levels as recommended by Schneider[10] and Nahum[7] are based upon an impact by a one-inch diameter impactor covered with a 0.1 inch layer of crushable nickel foam. With such a small impactor the force is concentrated on the bone in question. If the impact is to a large padded surface, the force is distributed over several facial bones and the tolerance level increases dramatically. For example, the minimum fracture level, as reported by Hodgson[11], for impact to the Zygoma is 360 pounds or almost twice that reported by Schneider. Hodgson used an impactor of 5.2 square inches covered with a one-inch urethane pad. Similarly, the mandible fracture level was considerably higher with the padded impactor.

The effectiveness of padding is illustrated in Reference 12. For a given impact, the head acceleration was reduced from over 400 g's to about 10 g's with two inches of padding.

Injuries to soft tissues can occur from impacting glass[12], small knobs, or hard surfaces, where the injury appears as a laceration but is actually a compression or explosion type of injury. Soft tissue injury to the upper lip, nose, and chin can be eliminated by adequate padding to distribute the force, especially over the facial bones.

Fracture of the nose occurs at low levels. A very soft padding of one inch or more in thickness will protect the nose by permitting the nose to sink into the padding and the major force then to be taken on other parts of the face.

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10. Schneider, D.C., and Nahum, A.M., "Impact Studies of Facial Bones and Skull," Proceedings of the Sixteenth Stapp Car Crash Conference, Detroit, Michigan, November, 1972.

11. Hodgson, V.R., "Tolerance of the Facial Bones to Impact," The American Journal of Anatomy, Dempster Memorial Issue, Vol. 120, No. 1, pp. 113-122, January, 1967.

12. Patrick, L.M., Lange, W.A., and Hodgson, V.R., "Facial Injuries - Causes and Prevention", Proceedings of the Seventh Stapp Car Crash Conference, Charles C. Thomas, Springfield, Illinois, 1965.

KNEE-THIGH-HIP COMPLEX IMPACT TO SEATS

- Injury Type: fracture of the patella, fracture of the femur, fracture of the pelvis, and/or joint injury.

- Human Tolerance: femur 1500 to 3800 pounds with a recommended value of 2000 pounds (MVSS 208 is 1700 pounds), patella 2000 pounds with padded surface, pelvis 2000 pounds with padded surface.

- Injury Source: knee impact to the back of the front seat, bulkhead, or other equipment.

King[13] has developed a femur load injury criterion based upon knee impacts and duration of impact. He feels that the 1700-pound femur criterion of MVSS 208 is conservative. This agrees with the data that Patrick generated which results in a load of 2000 pounds as being a reasonable value for the femur. Patrick[14,15] reports on impacts to a rigid padded surface with cadavers in a normal seated position. The load cells measured the force at the knee. Since the intact cadaver was used, the force applied to the knee could result in fracture to the patella, femur and/or pelvis. With a deformable structure that will deform at 1800 to 2000 pounds, there is little likelihood that fractures will occur except to individuals who are extremely weak in regard to knee impact.

FLEXION OR EXTENSION NECK INJURIES

- Injury Type: Soft tissue, cervical vertebra fracture or basilar skull fracture.

- Human Tolerance: Extension 35 foot-pounds around the occipital condyles produced no injury in a volunteer, and 42 foot-pounds is a threshold of injury from cadaver experiments. The equivalent torque at the occipital condyles in flexion is 65 foot-pounds for voluntary minor injury and 140 foot-pounds to cadavers. Compres-

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13. King, J.J., Fan, W.R.S., and Vargovick, R.J., "Femur Load Injury Criteria - A Realistic Approach", Proceedings of Seventeenth Stapp Car Crash Conference, Oklahoma City, Oklahoma, November, 1973, SAE Paper No. 730984.

14. Patrick, L.M., and Mertz, H.J., "Cadaver Knee, Chest and Head Impact Loads", Proceedings of the Eleventh Stapp Car Crash Conference, October, 1967, Anaheim, California, SAE Paper No. 670913.

15. Patrick, L.M., Kroell, C.K., and Mertz, H.J., "Forces on the Human Body in Simulated Crashes", Proceedings of the Ninth Stapp Car Crash Conference, Nolte Center for Continuing Education, University of Minnesota, 1966.

sion or tension and bending tolerance is unknown, but is lower than the inertia tolerances for flexion and extension.

Research has shown that the torque at the occipital condyles is the best measure of injury potential as a result of inertia loading in flexion or extension[16, 17, 18]. In addition to the torque at the occipital condyles from the inertial loading, there is a shear and axial load applied at the occipital condyles. Experimental results indicate that these loads are well below the voluntary static limit when the torque exceeds the injury limit. Therefore, the shear and axial load under inertial loading conditions are not limiting factors.

During the extension of the head and neck during inertia loading (the so-called whiplash syndrome), soft tissue is injured more often than bone. Ligaments, muscles, and complex tissue attachments between the cervical vertebra are vulnerable to injury. Experimental programs with volunteers and cadavers indicate that there are no injuries until the angle between the head and neck reaches or exceeds a critical value. Consequently, hyperextension and hyperflexion injuries can be avoided by providing a suitable support to keep the head from rotating more than a predetermined amount with respect to the torso. The limiting angle appears to be approximately 80 degrees between the head and the torso, measuring from the normal head position.

In a volunteer program[16, 17, 18] the static torque at the occipital condyles in extension was 17.5 foot-pounds maximum and was limited by the strength of the volunteers' neck muscles. No injury resulted at 35 foot-pounds at the occipital condyles and approximately 80 degrees between the torso and the head. Under the same conditions, ligamentous damage was observed in embalmed cadavers at 42 foot-pounds.

Under conditions producing flexion of the head and neck, the chin strikes the chest in hyperflexion. The external force applied to the chin is not easily measured without modifying the angle through which the head and neck can travel. Therefore, Mertz[16] has calculated an equivalent torque in which the force on the chin is assumed to produce a change in the head acceleration equivalent to a given torque at the

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16. Mertz, H.J., "The Kinematics and Kinetics of Whiplash," Ph.D. Dissertation, Wayne State University, 1967.

17. Mertz, H.J., and Patrick, L.M., "Investigation of the Kinematics and Kinetics of Whiplash", Proceedings of the Eleventh Stapp Car Crash Conference, Society of Automotive Engineers, Inc., New York, 1967.

18. Mertz, J.J., and Patrick, L.M., "Strength and Response of the Human Neck", Fifteenth Stapp Car Crash Conference, Coronado, California, November 17-19, 1971, SAE Paper No. 710020.

occipital condyles. Under these conditions, the static torque for a human volunteer is 26 foot-pounds. Under dynamic conditions the pain threshold is 44 foot-pounds and the maximum dynamic torque sustained by a volunteer was 65 foot-pounds. At the 65 foot-pound level, the volunteer had considerable pain in the neck and upper torso area for approximately one week with no permanent injury.

In both extension and flexion, the neck muscles play a role in minimizing the torque at the occipital condyles in low-level collision simulations. At the higher levels, the neck muscles cannot reduce the torque at the occipital condyles to a sub-injury level.

STANDEES STRIKING STANCHIONS OR BULKHEADS

- Injury Types: Whole body deceleration injuries from striking a stanchion with deflection around the stanchion and concentrated loads and whole body deceleration from striking a bulkhead.

- Human Tolerance: The tolerance for head impact, knee impact and face impact will be the same as provided under the main headings herein for those body components. Little is known about the tolerance to concentrated loads from impact to a stanchion except for the head for which the tolerances are listed under that heading. For short duration impacts to the chest, a 60 g for 3 milliseconds exclusion has been recommended for automotive use as has a Gadd Severity Index of 1000 maximum. These values probably represent a greater injury than is acceptable for intercity railcars. Therefore, a 40 g for 3 milliseconds exclusion is suggested.

When striking a bulkhead, the force will probably be distributed over a large part of the body; consequently, with suitable padding to prevent localized forces in the injurious range, the occupants should survive the 20 mph velocity impact with no more than minor injury. It is proposed that the bulkheads be designed with sufficient padding and/or deformation to permit a 20 mph impact of the occupant with a maximum of 40 g's measured at the cg of the thorax. With the bulkhead so designed, the head impact should be well under the maximum allowable HIC 1000.

The stanchion or grab bar impact is more critical and must be deformable to obtain additional stopping distance over that required for the 40 g whole body deceleration into the bulkhead. Local area impacts would have tolerances similar to those described for that particular area.

FLAILING LIMBS

- Injury Types: Fracture of the long bones of the arm and legs and injury to joints.

- Human Tolerance: Impacts to the tibia with a hard surface from a cylindrical pendulum with the axis of the cylinder perpendicular to the long axis of the tibia resulted in impact ranging from 225 pounds to 1330 pounds causing fracture according to one investigator, and 1000 to 1500 pounds applied at the distal 1/3 of the tibia reported by a second investigator.

Kramer[19] conducted tests on the lower limbs of 200 cadavers. He used a dual pendulum in which the cadaver, lying on its side, was swung in an arc and made contact at the bottom of the arc with a second pendulum consisting of cylinders 5.7 or 8.5 inches in diameter. The forces measured ranged from 225 to 1330 pounds at fracture. The impact site varied from just below the knee to the distal end of the tibia. The maximum values were lower for females than for males.

Young[20] found a range of 1000 to 1500 pounds when impacting the tibia at the distal third. His value corresponds to the upper end of the fracture range found by Kramer[19].

Flailing limbs coming in contact with a hard surface that concentrates the force near the center of the long bone will produce bending plus concentrated loads at the point of impact. When the force exceeds the fracture level, including the effect of the concentrated load on the bone, fractures will occur. The danger of fracture can be reduced by distributing the force over a substantial length of the bone and by padding the contact areas to avoid the concentrated loads at point of contact.

Information on the forces which cause fracture in bending of the long bones of the arm was not available. To minimize the danger of fracture of the long bones of the limbs, it is suggested that the tolerance level be established at the midrange of the data presented by Kramer, approximately 750 pounds. At the 20-mph collision condition, it is anticipated that the forces can be reduced to a value below the fracture level by a reasonable amount of padding, the required thickness of which will decrease as the radius of the rigid component increases.

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19. Kramer, M., Burow, K., and Heger, A., "Fracture Mechanism of Lower Legs Under Impact Load," Proceedings of Seventeenth Stapp Car Crash Conference, November 12-13, Oklahoma City, Oklahoma, SAE Paper No. 730966.
20. Young, J.W., "Threshold Value for Tibia Fracture, Male Cadavers (aged 29-57)", 1967 (unpublished).

BACK INJURIES FROM FLEXION, EXTENSION, AND/OR CAUDAL CEPHALAD LOADING INCLUDING FALLS

- Injury Type: Bone fracture, intervertebral disc damage, injury to connecting tissues.

- Human Tolerance: Caudal cephalad direction with optimal restraints (pilot ejection seats), 20 g's for lower dorsal or lumbar vertebra fracture. Average 600 pounds for fracture of the endplate for excised vertebra. Tolerance is very low for individuals with weak backs or those with previous injuries. For flexion with a lap belt only, the tolerance is approximately 2000 pounds.

Ejection seats designed for a maximum of 20 g acceleration have been successful in saving lives, but have caused several fractured vertebrae. Consequently, the 20 g limit is probably too great for the average individual. In a fall from 4 feet, assuming a half sine deceleration pulse and a direct impact on the buttocks, a 3.6-inch decelerating distance is required if the peak acceleration is not to exceed 20 g's. From a 2-foot fall under the same conditions, a 2.3-inch decelerating distance is required. This explains the numerous injuries that occur when people fall in a seated position to a hard surface. Furthermore, the average unrestrained individual is not able to withstand the 20 g's that the fully restrained military pilot can sustain with only occasional fractures. It is obvious that the average individual falling in awkward positions and landing on his buttocks can and does receive serious back injuries in many cases in falls from low heights. Since it is impossible to put sufficient padding on the floor and approaches to the railcar, the prevention of such injuries must be relegated to preventing the falls.

Human volunteers have been subjected to deceleration conditions with lap belts at forces of 2000 pounds or greater, without injury. Again, these were young males in good physical condition and do not represent the average population. The lap belt flexion or jackknifing comes the closest to the jackknifing over a seat back, armrest, table, etc. for which the force measurements have been made.

Extension of the back over an object of small cross sectional area will produce a concentrated load on the back and can produce injuries at comparably low forces. While quantitative data is unavailable on the forces required, they are thought to be small for producing injury.

THORAX IMPACT

- Injury Types: Injuries to the thorax from striking the seat back in front during forward force collisions. The injuries include rib fractures, sternal fractures, and thoracic viscera injuries.

- Human Tolerance: The human tolerance to chest impact is dependent upon the area of contact. Patrick[14] reports approximately 1000 pounds for rib fracture from impact to a 6-inch diameter padded target. Kroell[21] reports about 800 pounds as the fracture limit with a 6-inch diameter unpadded impactor. Kroell further notes that force is not as good a criterion as deflection of the chest for indicating injury potential. If the force is distributed over a substantial part of the thorax the recommended tolerance is 40 g for 3 millisecond exclusion.

Chest impact with a well-padded surface should result in a distributed force which will minimize the danger of rib fractures or other injury from concentrated forces. If the force is distributed over the rib cage without concentrated forces, the 40 g for 3 millisecond tolerance level is recommended as a conservative value. For automotive collisions with the chest, impact to the steering assembly or the instrument panel is 60 g for 3 milliseconds. However, for the 20-mph low injury level requirements of the rail cars the 40 g value is recommended.

Patrick,[14] with a limited number of cadavers impacting a 6-inch diameter target with 15/16 of an inch padding, found a fracture level at about 1000 pounds. Kroell,[21] with a 6-inch diameter unpadded impactor, found fractures at approximately an 800-pound plateau.

BENDING FRACTURE AND/OR SPRAIN TO LOWER LIMBS FROM AN ENTRAPMENT OF THE LOWER LEG BETWEEN THE FLOOR AND THE BOTTOM OF THE SEAT IN FRONT OF THE OCCUPANT

Tolerance for this specific condition is unknown. The only tolerance that can be applied is the force to the tibia that was reported under the heading of flailing limbs. If the 1000-pound tolerance is assumed at the midpoint of the tibia or approximately 8 inches above the floor, and the cg of the occupant is assumed to be 40 inches above the floor with the

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21. Kroell, C.H., Schneider, D.C., and Nahum, A.M., "Impact Tolerance and Response of the Human Thorax II", Proceedings of Eighteenth Stapp Car Crash Conference, Ann Arbor, Michigan, December 4-5, 1974, SAE Paper No. 741187.

legs straight, a simple calculation shows that a force of 167 pounds applied at the 40-inch cg height will produce 1000 pounds at the 8-inch height of the tibia. This corresponds to approximately 1 g applied to the occupant. With several g's expected in a 20 mph collision, the only mitigation for this type of injury is to prevent the leg from being trapped beneath the seat.

OCCUPANT-TO-OCCUPANT IMPACT WHEN PASSENGER SEATS FACE EACH OTHER

Huelke[22] reports on occupant-to-occupant injuries in automobile collisions. He found that occupant-to-occupant contact is a frequent cause of injury occurring in about 22 percent of the cars in injury crashes in which there was more than one occupant. The injuries from occupant-to-occupant contact are frequently worse than minor on the Abbreviated Injury Scale. It should be noted that in automobile collisions, the occupants are seated side-by-side or in front and rear seats. In all cases they move in the same direction during impact. In the railcar with seats facing each other, the occupant on the impact side will be retained by the seat and will be impacted against the seat by the facing passenger. They will probably be subjected to more serious injuries than those in which the occupants are free to move in the same direction. The exception in the case of the automobile is a side impact in which the side-by-side occupants move together with the occupant on the impact side being crushed between the occupant and the side of the vehicle.

Elimination of occupant-to-occupant injuries can be achieved by eliminating the facing seats.

Table A-2 summarizes the injury data presented in this section. As will be noted, there are gaps in the table where tolerance levels are unknown for the particular exposure. Further research with cadavers and/or human volunteers is necessary to obtain this data.

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22. Huelke, D.F., Sherman, H.W., and O'Day, J., "The Hazard of the Unrestrained Occupant", Proceedings of the Eighteenth Conference of the American Association for Automotive Medicine, Toronto, Ontario, September 12-14, 1974.

TABLE A-2. HUMAN TOLERANCE SUMMARY

INJURY SOURCE	INJURY TYPE	HUMAN TOLERANCE	INJURY MECHANISM	INJURY MITIGATION
HEAD IMPACT	BRAIN INJURY, SKULL FRACTURE, SCALP LACERATION	HIC=1000 WITH A GOAL OF 500	HUMAN IMPACT TO BACK OF SEAT OR GRAB RAIL	PADDING AND CONTI DEFORMATION
FACE IMPACT	FACIAL BONE FRACTURE, SOFT TISSUE AND EYE INJURY	APPROXIMATELY 200 LBS TO INDIVIDUAL FACIAL BONES	FACE IMPACT TO BACK OF SEAT OR GRAB RAIL	PADDING AND CONTI DEFORMATION
KNEE IMPACTS	FRACTURE OF PATELLA, FEMUR OR PELVIS, AND JOINT INJURY	KNEE IMPACT OF 2,000 POUNDS	KNEE IMPACT TO BACK OF SEAT	PADDING AND CONTI DEFORMATION
FLEXION OR EXTENSION NECK INJURIES	SOFT TISSUE DAMAGE, CERVICAL VERTEBRAE, OR BASILAR SKULL FRACTURE	EXTENSION 42 LB-FT, FLEXION-EQUIVALENT OF 65 LB-FT.	FLEXION OR EXTENSION OVER SEAT BACK	HIGH SEAT BACK, HE SUPPORT OR CONTR MOVEMENT
STANDEES STRIKING STANCHION OR BULKHEADS	WHOLE BODY DECELERATION	40g RECOMMENDED FOR WHOLE BODY WITH HEAD, FACE, AND KNEES AS REPORTED UNDER SEAT IMPACTS	IMPACT TO STANCHION OR BULKHEAD	PADDING OR CONTR DEFORMATION
FLAILING LIMBS	FRACTURE OF LONG BONES AND JOINT INJURY	TIBIA IMPACT 1000 LB, UPPER LIMBS UNKNOWN	FLAILING LIMBS STRIKING STANCHION OR OTHER SMALL DIAMETER OBJECTS	PADDING AND CONT DEFORMATION
BACK INJURIES FROM FALLS OR BENDING	VERTEBRAE FRACTURE, DISC DAMAGE, CONNECTING TISSUE INJURY	CAUDO-CEPHALAD-20g's ENDPLATE FRACTURE – 600 LBS FLEXION 2000 APPLIED TO LAP BELT EXTENSION-UNKNOWN	FALLS OR BENDING OVER SEAT BACK	NONSKID FLOORS, H GRIPS AND HIGH SE

TABLE A-2 - CONTINUED

INJURY SOURCE	INJURY TYPE	HUMAN TOLERANCE	INJURY MECHANISM	INJURY MITIGATION
THORAX IMPACT	RIB FRACTURE, STERNAL FRACTURE, THORACIC VISCERA INJURIES	1000 LB FOR 6-INCH DIA PADDED IMPACT AREA, 40g/3ms FOR DISTRIBUTED LOAD	IMPACT TO SEAT BACK	PADDING AND CONTROLLED DEFORMATION
CRUSHING FROM PEOPLE PILING INTO BULKHEADS	CRUSHING OF BODY AND/OR JOINT DISLOCATION	UNKNOWN	CRUSHING	ELIMINATION OF STANDEES OR SEGREGATION TO PREVENT SEVERAL OCCUPANTS PILING INTO A BULKHEAD
BENDING FRACTURE OR SPRAINS FROM LOWER LIMB ENTRAPMENT	BENDING FRACTURE OF LONG BONES OR JOINT DISTORTION	UNKNOWN	BENDING OF LOWER LIMBS DUE TO ENTRAP-MENT OF LOWER PART OF LOWER LIMB UNDER SEAT	ELIMINATE OR LIMIT SPACE BETWEEN BOTTOM OF SEAT AND FLOOR SO FOOT CANNOT BECOME ENTRAPPED
OCCUPANT-TO-OCCUPANT IMPACT	IMPACT INJURY FROM HEAD OR OTHER BODY PART IMPACT-ING ANOTHER OCCUPANT	UNKNOWN	ONE OCCUPANT HITTING ANOTHER DURING COLLISION MOVEMENT. MAJOR PROBLEM IS WITH FACING SEATS	ELIMINATE FACING SEAT DESIGN

APPENDIX B
NEW TECHNOLOGY

Although no innovation, discovery, or invention was made in the performance of the work, the engineering standards prepared on pages 5ff are innovative, and indicate for the first time areas where substantial improvements could be provided in occupant protection in intercity passenger-carrying vehicles.