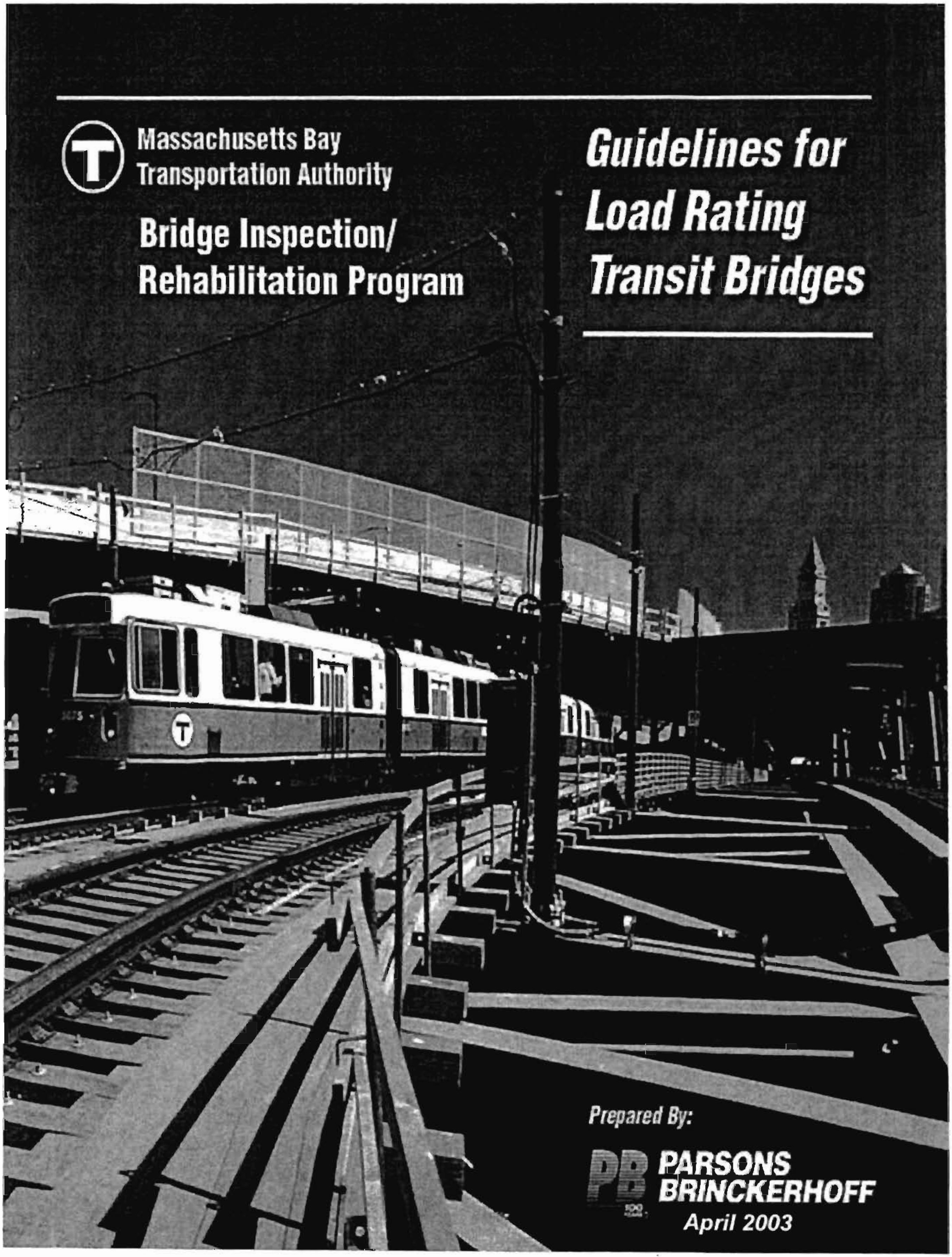
Massachusetts Bay Transportation Authority

Bridge Inspection/ Rehabilitation Program

Guidelines for Load Rating Transit Bridges



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A. GENERAL

A. I **Assumptions**. These specifications shall be used for determining the live load capabilities of existing transit bridges. They provide a basis for computing the maximum loads that may be allowed on a bridge when materials are of good quality, members are acting normally, and deductions in size or area have been made for deteriorated portions. They are based generally on the Second Edition including Interims thru year 2001 for the Manual for Condition Evaluation of Bridges, AASHTO 1994, and the 16th Edition and Interims thru 2002 of the Standard Specifications for Highway Bridges as published by the American Association of State Highway and Transportation Officials (AASHTO) and the 2002 edition of the American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering. The rating of existing bridges in terms of carrying capacity shall be determined by the computation of stress based on authentic records of the design, details, materials, workmanship, and physical condition, including data obtained by inspections and/or tests. At the actual time of rating the latest above editions, interims, etc. shall be used.

A.2 **Use and Modification of Standard Design Specifications.** For all matters not definitely covered by these specifications, the current standard AASHTO or AREMA specifications used for the design of new bridges shall be used as a guide. However, there may be instances in which an Engineer, based on knowledge of the condition and performance characteristics of a bridge under traffic, may make a judgment that the action of a member within the structure is not consistent with the design concept of the controlling specifications. In this situation, the Engineer may modify the design criteria within safe limitations and, following sound principles of engineering mechanics, base the capacity analysis for the member on its know action under load. Deviations from controlling specifications shall be fully documented.

A.3 **Rating Levels:** Transit Bridges shall be load rated at two levels, Inventory and Operating. The Inventory rating level generally corresponds to the customary design level of stress, but reflects the existing bridge and material conditions with regard to deterioration and loss of section. Load ratings based on the Inventory level allow comparisons with the capacity for new structures and therefore results in a live load which can safely utilize an existing structure for an indefinite period of time.

Load ratings based on the Operating rating level generally describe the maximum permissible live load to which the structure may be subjected, at infrequent intervals, with specified speed restrictions. Fatigue need not be considered when determining Operating Ratings.

Calculation of stresses shall be by the working stress method using English units of measure.

A.4 Rating of Substructures

In general, substructure elements, except steel, timber, and pile bent structures, shall not be rated unless, in the opinion of the engineer, this will influence the rating of the bridge. Careful attention should be given to all elements of the substructure for evidence of instability, which affects the load-carrying capacity of a bridge. Evaluation of the conditions of a bridge 's substructure will in many cases be a matter of good engineering judgment. The rating report shall contain a statement noting the engineer's judgment with regards to the substructure. Substructure elements that are to be rated shall be rated using the Load Factor method.

B. LOADINGS

B. I **Dead Loads.** (D) The dead load of the structure shall be computed in accordance with the conditions existing at the time of analysis.

(a) In estimating the weight for the purpose of computing dead load stresses, the following-unit weights shall be used:

	Pounds per cubic foot
Steel	490
Concrete	150
Sand, gravel, and ballast	120
Asphalt-mastic and bituminous macadam	150
Granite	170
Paving Bricks	150
Timber	60

(b) The track rails, third rail, inside guard rails, and their rail fastenings shall be assumed to weigh a minimum of 200 lb. per lineal foot for each track. Electrification including third rail and fasteners shall be assumed to weigh a minimum of 60 pounds per lineal foot of track.

B.2 **Live Loads.** (L) The live or moving axle loads and their spacing to be applied to each track on the structure for determining the Inventory and Operating Ratings shall be as follows:

B 2.1 Revenue Vehicles - Normal Consists

Dimensions, axle loads, and normal consist range shall be as shown in Figure A. Car combinations shall be within the minimum and maximum range whichever produces the most critical conditions.

B2.2 Revenue Vehicles - Extraordinary Consists

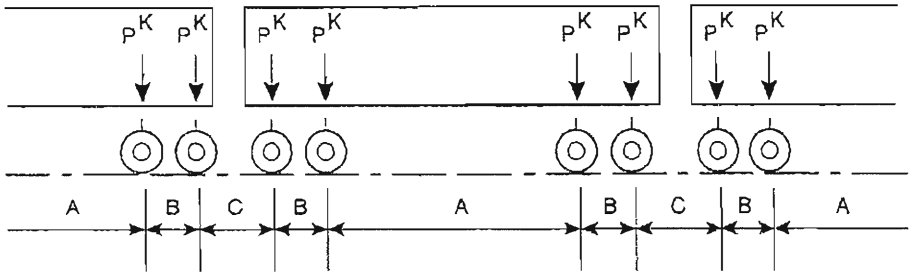
For long spans, a special case shall be evaluated which represents a disabled train being pushed by an operating train. For this case, the total consist shall be twice the normal standard consist. Impact shall be applied for a speed of 20 MPH. The adjacent tracks shall be loaded with normal consists without speed reduction.

B2.3 Work Cars

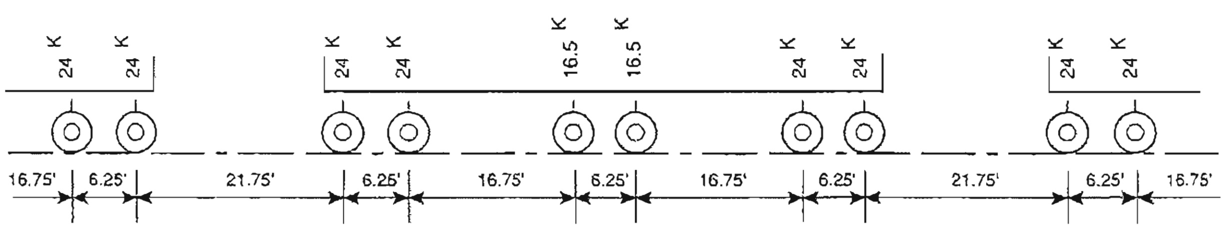
Dimensions and axle loads shall be as shown below in Table 1. Work car consists shall be as indicated in Table 2. however, impact and centrifugal forces shall be reduced to account for a maximum speed of 40 MPH. All tracks shall be loaded with work cars. Fatigue requirements shall not be evaluated for work cars.

The axle load for both revenue and work cars shall be applied vertically with 50 percent of each axle load applied equally at the top of each rail.

MBTA BRIDGE MANAGEMENT PROGRAM
NORMAL CONSIST
LOAD RATING VEHICLES
REVENUE RAIL TRANSIT AW3 CRUSH LOADED



LINE	CAR	DIMENSIONS A	B	C	AXLE WEIGHT P=	TOTAL WEIGHT	MIN-MAX CONSIST
Blue	#5	24.5'	6.83'	10.67'	23^K	92^K	2 to 6 Cars
Orange	#12	39.67'	6.83'	12.0'	26^K	104^K	2 to 6 Cars
(OHBL)*	#4	24.5'	6.83'	10.67'	21.5^K	86^K	2 to 8 Cars
Red	#3	44.17'	6.83'	12.0'	30^K	120^K	2 to 6 Cars
Ashmont-** Mattapan	PCC	16.75'	6.00'	18.67'	15^K	60^K	1 to 2 Cars



LINE	CAR	(AXLE LOADS SHOWN)	TOTAL WEIGHT	MIN-MAX CONSIST
Green	#7 SRC		129^K	1 to 3 Cars

* Overhauled Blue Line Car Used on Orange Line

** Ashmont-Mattapan Structures Will Also Be Rated For #7 Cars (SRC) - 1 to 2 Cars

Note: Future Car Loads Will Be Used When Available if Higher

3/03/03

Figure A Revenue Vehicles

Work Car Type	Design Total Load (lbs)	Design Axle Load (lbs)
#0526 Flat Car	76,400	19,100
#01400 Motor Car	114,000	28,500
#04441 Flat Car with Crane	100,000	25,000
#04443 700 HP Diesel Locomotive	100,000	25,000
#04446 Flat Car	102,400	25,600
#04447 Flat Car	102,400	25,600
#04449 Flat Car	100,000	25,000
Ballast Car	76,000	38,000
Tamper Car	70,000	35,000

Table 1 Rail Transit Work Car Loads

(For Work Car configuration see Appendix B)

Consist Type	Work Car Combinations
I	700 HP Diesel Locomotive (04443) + Two Ballast Cars + One Tamper
II	Two Flat Cars (#04446/#04447) + Flat Car With Crane (#04441)
III	700 HP Diesel Locomotive (04443) + Flat Car (#0526)
IV	Flat Car (#04449) + Four Work Motor Cars (#01400 Series)
V	700 HP Diesel Locomotive (04443) + Four Ballast Cars
VI*	700 HP Diesel Locomotive (04443) + Two Ballast Cars followed by 700 HP Diesel Locomotive (04443) + Two Ballast Cars followed by 700 HP Diesel Locomotive (04443) + Two Ballast Cars

*This combination shall be used for long and multiple span structures to provide maximum loading condition. There shall be 1,000 ft distance between moving trains on the same track at full speed. This distance diminishes to zero for stationary trains.

Table 2 Rail Transit Work Car Combinations

NOTE: For most simple spans to 150 feet, Consist Type V governs for both shear and moment. For other spans including continuous spans the rating engineer shall verify the maximum cases for maximum moment and shear. For continuous spans, where necessary, the rating engineer shall minimize any consist (i.e. ---eliminate car or cars) to cause maximum stress.

B.3 Impact Load (I)

(a) Impact load shall be determined by taking a percentage of the live load specified and shall be applied vertically and equally at top of each rail.

The percentage to be used for impact shall be computed from the following formulas:

$$I = \frac{50}{L+125} \quad (30\% \text{ Max})$$

where L = length, ft., center to center of supports for stringers, transverse floorbeams without stringers, longitudinal girders and trusses (main members), or

L = length, ft., of the longer adjacent supported stringers, longitudinal beam, girder or truss for impact in floorbeams, floorbeam hangers, subdiagonals of trusses, transverse girders, supports for longitudinal and transverse girders and viaduct columns. For continuous spans the length of span under consideration for positive moment; and the average of two adjacent loaded spans for negative moment.

(b) For members receiving load from more than one track, the impact percentages shall be applied to the live load on the number of tracks shown below:

Two tracks - full impact on two tracks.

More than two tracks - full impact on any two tracks which produces the critical loading.

(c) <u>Items to Which Impact Applies</u>

- Superstructure, including steel or concrete supporting columns, steel towers, legs of rigid frames, and generally those portions of the structure which extend down to the main foundation.
- The portion of concrete or steel piles above the ground line which is connected to the superstructure as in rigid frames and continuous designs.
- For structures having cover of less than 4 feet, full impact of the Vehicle loading at 1 foot cover proportioned down to zero at 4 feet cover.

(d) Items to Which Impact Does Not Apply

- Abutments, retaining walls, wall-type piers and piles.
- Foundations and footings.
- Culverts and structures having a cover of 4 feet or more.
- Concrete subway or depressed section slab resting on earth.

B.4 Centrifugal Load (CF)

(a) On curves, a centrifugal load corresponding to each axle load shall be applied horizontally through a point 5 ft. above the top of the low rail. This load shall equal the percentage of the specified axle load without impact.

$$CF = 0.00117S^2D \text{ or } C = \frac{100V^2}{32.2R}$$

Where S = speed, miles per hour

D = degree of curve

V = speed, feet per second

R = radius of curve in feet

(b) On curves, the effect of the couple on a stringer, girder, or truss toward the outside and inside of curve shall be determined separately. For members toward the outside of curve, the centrifugal load shall apply. For members toward the inside of the curve, any effect of the centrifugal load shall be omitted.

(c) Substructures shall be evaluated for the effect of the horizontal load applied as specified in (a) above.

(d) For rating purposes S shall be assumed at 60MPH.

B.5 Lateral Load from Wind (W) including Nosing

A lateral load of 450 lbs. per lineal foot shall be applied as a moving load in a horizontal direction. This is to consist of, 150 lbs. per lineal foot for nosing, transversely applied at the base of rail and 300 lbs. per lineal foot for wind in any horizontal direction applied at 6 1/2 feet above the top of rail. In addition to the above, a lateral load of 30 lbs. per square foot of all exposed surfaces of girders or truss members, and substructure for wind from any direction. For girder spans use 1.5 times the vertical projection of the span.

B.6 Longitudinal Force (LF)

(a) The longitudinal force resulting from the starting and stopping of trains shall be taken as 15 percent of the live load without impact. This force shall be taken on one track for two-track systems, and shall be applied to the rails and supporting structure as a uniformly distributed force at the top of rail. For three or more track systems, the longitudinal force shall be applicable to any two tracks simultaneously.

(b) Where the rails are not continuous (broken by a movable span, sliding rail expansion joints, or other devices) across the entire bridge from embankment to embankment, the effective longitudinal load shall be taken as the entire load specified in (a).

B.7 Thermal Forces (T)

Stresses set up by thermal forces shall not be considered except for structures such as long span bridges and concrete arches unless the Engineer as a result of his/her investigation, determines that they are especially important. Refer to AREMA for loads and forces.

B.8 Friction Force (F)

For sliding shoes supporting bridge members, friction applicable to the material shall be used, but in no case less than 10 percent of the vertical load.

C. LOAD COMBINATIONS FOR RATINGS

C. 1 Inventory Rating

DL + LL + I + CF @ 100% of inventory stress
DL + LL + I + CF + W + LF + F @ 125% of inventory stress

C.2 **Operating Rating**

DL + LL + I + CF @ 100% of operating stress
DL + LL + I + CF + W + LF + F @ 125% of operating stress

C.3 Wind, LF, and F will normally be considered when rating column bents, towers, and piers unless the Engineer, as a result of his/her investigation determines they are important in other members.

C.4 Where two or more methods of analysis are valid, that which gives the higher rating shall govern. Alternate methods of analysis are not necessary if the method used indicates that the bridge can carry the specified inventory loads.

When the controlling inventory rating is less than the weight of the rating revenue vehicle, additional calculation shall be made to determine at what speed the rating vehicle may operate over the bridge.

Similarly when the operating rating is less than the weight of the rating work car, additional calculations shall be made to determine at what speed work cars may operate over the bridge. If additional capacity is required for work cars, reducing the number of cars in the consist, reducing speed, and limiting loads to one track shall also be evaluated.

D. RATING VEHICLE SPEED

D. I The rating speed used for the inventory and operating rating of the Revenue Vehicles, Normal Consists shall be 60 mph except as limited by the superelevation, or grades of the track at the location of the structure, but only after permission has been given to use a lower rating speed-. If a lower rating speed is used, it shall be stated in the rating assumptions and the rating load summary sheet shall have this value noted.

D.2 Reduction may be made in the impact percentage for speeds below 60 mph by the following factor:

$$\left[1-\frac{0.8}{2500}(60-S)^2\right] \geq 0.2 \text{ where S = speed in mph.}$$

Corresponding speeds shall be used to calculate a revised centrifugal load.

E. DISTRIBUTION OF LIVE LOADS

E. I **General**

The following conditions shall be accounted for in the analysis of the structure:

(a) The increased load carried by any truss, girder, stringer, or floor member due to load eccentricity (this will occur where bridges are on tangent and the tracks are off center and where bridges are on curves).

(b) For members receiving load from more than one track, the design live load on the tracks shall be follows:

For two tracks, full live load on two tracks.

For three tracks, full live load on two tracks and one-half on the other track.

For four tracks, full live load on two tracks, one-half track, and one-quarter on the remaining track.

For more than four tracks, as specified by the Engineer.

The selection of the tracks for these loads shall be such as will produce the greatest live load stress in the member being rated.

E.2 **Ballasted Deck Structures**

(a) The designated lateral and longitudinal distribution of live load is based on the following assumptions:

1. Standard cross ties shall be used which are not less than 8 ft long approximately 8 in. wide and spaced at not over 24 in. on centers. If another type of tie or greater spacing is used, the rating shall be modified for the greater load concentrations.

2. Not less than 6 in. of ballast shall be provided under the ties.

3. The designated widths for lateral distribution of load shall not exceed 14 ft., the distance between track centers of multiple track structures, nor the width of the deck between ballast retainers.

4. The effects of track eccentricity and of centrifugal load shall be included.

(b) Ballasted Concrete Structures

1. The axle loads on structures may be assumed as uniformly distributed longitudinally over a length of 3 ft., plus the depth of ballast under the tie, plus twice the effective depth of slab, limited, however, by the axle spacing or 7 feet.

2. Live load from a single track acting on the top surface of a structure with ballasted deck or under fills shall be assumed to have uniform lateral distribution over a width equal to the length of track tie plus the depth of ballast and fill below the bottom of tie, unless limited by the extent of the structure.

3. The lateral distribution of live load from multiple tracks shall be as specified for single tracks and further limited so as not to exceed the distance between centers of adjacent tracks.

4. The lateral distribution of the live load for structures under deep fills carrying multiple tracks shall be assumed as uniform between centers of outside tracks, and the loads beyond these points shall be distributed as specified for single track. Widely, separated tracks shall not be included in the multiple track group.

(c) Ballasted Steel Structures

1. Deck

a. Each axle load shall be uniformly distributed longitudinally over a length of 3 ft. plus the minimum distance from bottom of tie to top of beams or girders, but not to exceed 7 ft. nor the minimum axle spacing of the load system used.

b. In the lateral direction the axle load shall be uniformly distributed over a width equal to the length of tie plus the minimum distance from bottom of tie to top of beams or girders.

c. The thickness of the deck shall not be less than 1/2 in. for steel plate, 3 in. for timber, or 6 in. for reinforced or prestressed concrete.

2. Transverse Steel Beams

a. For ballasted decks supported by transverse steel beams without stringers, the portion of the maximum axle load on each beam shall be as follows:

$$P = \frac{1.15AD}{S}$$

Where P = load on a beam from one track

A = axle load

S = minimum axle spacing, ft.

d = beam spacing, ft.

a = beam span, ft

n = the ratio of the modulus of elasticity of steel to that of concrete

I = moment of inertia of beam $(in)^4$

h = thickness of concrete deck slab, in.

$H = nI/ah^3$

D = effective beam spacing, ft.

For moment: $$D = d\left(\frac{1}{1+\frac{d}{aH}}\right)\left(0.4+\frac{1}{d}+\frac{\sqrt{H}}{12}\right)$$

but not greater than d or S.

For end shear: D = d

b. The load P shall be applied as two equal concentrated loads on each beam at each rail, equal to P/2. No lateral distribution of such loads shall be assumed

c. D = d for bridges without a concrete deck; or for bridges where the concrete slab extends over less than the center 75% of the floorbeam.

d. Where d exceeds S, P shall be the maximum reaction of the axle loads, assuming that the deck between the beams acts as a simple span.

e. For bridges with concrete decks, the slab shall be rated to carry its portion of the load.

3. Longitudinal Steel Beams or Girders

a. Where beams, or girders are spaced symmetrically about the centerline of tangent track, the axle loads shall be distributed equally to all beams or girders whose centroids are within a lateral width equal to the length of tie plus twice the minimum distance from bottom of tie to top of beams or girders, but no greater than the track centers or 7 feet each side of the center line of track. Distribution of loads for other conditions shall be determined by recognized methods of analysis.

b. For the rating of beams or girders, the live load shall be considered as a series of concentrated loads. No longitudinal distribution of such loads shall be assumed.

E.3 Open Deck Structures

(a) Timber bridge ties shall be rated (assuming ties spaced not further than 6 in. apart) based on the assumption that the maximum wheel load on each rail is distributed equally to all ties or fractions thereof within a length of 4 ft. but not to exceed 3 ties and is applied without impact for the tie rating only.

(b) For the rating of beams or girders, the live load shall be considered as a series of concentrated loads. No longitudinal distribution of such loads shall be assumed.

(c) Where two or more longitudinal beams per rail are properly diaphragmed and symmetrically spaced under the rail, they may be considered as equally loaded.

F. SPAN LENGTHS

F.1 Concrete Structures

(a) Span length of members not built integrally with supports shall be considered the clear span plus depth of member, but need not exceed distance between centers of supports.

(b) In analysis of continuous and rigid frame members, center-to-center distance shall be used in the determination of moments. Moments at faces of support may be used for member rating. When fillets making an angle of 45 degrees or more with the axis of a continuous or restrained member are built monolithic with the member and support, face of support shall be considered at a section where the combined depth of the member and fillet is at least one and one-half times the thickness of the member. No portion of a fillet shall be considered as adding to the effective depth.

(c) Effective span length of slabs shall be as follows:

1. Slabs monolithic with beams or walls (without haunches), S = clear span.

2. Slabs supported on steel stingers, S = distance between edges of flanges plus 1/2 the stringer flange width.

F.2 **Steel Structures**

(a) The length of span or member shall be assumed as follows:

For trusses and girders, the distance between centers of bearings.

For truss members, the distance between centers of joints.

For floorbeams, the distance between centers of trusses or girders.

For stringers, the distance between centers of floorbeam.

For timber bridge ties, the clear distance between supports plus 6 in.

(b) The depth shall be assumed as follows:

For trusses, the distance between gravity axes of chords.

G. STRESSES

G. 1 Computation of stresses

(a) Stresses shall be computed for the details as well as the main members, giving particular attention to:

1. Lacing and forked ends of compression members, eccentricity of riveted joints and connections, unequal stress in tension members, and secondary stresses.

2. Pin plates of tension members. The following rules are given as a guide for those cases where the body of the member is carrying the limiting stress:

    a. The net section through the pin hole transverse to the axis of the member should be 40% greater than the net section of the member.

    b. The net section beyond the pin hole on any line parallel to the axis of the member should be not less than three-fourths of the net section of the member.

H. ALLOWABLE STRESS METHOD

H.1 General

The live loads combination on any structure, when combined with all other loads, shall not produce stresses exceeding those allowable stresses set forth hereinafter. These stresses shall only be used when, in the judgment of the Engineer, the materials under. consideration are sound and reasonably equivalent in strength to new materials of the grade and qualities that would be used in first class construction.

When the grading or manufacture is sub-standard, the allowable stresses shall be fixed by the Engineer, based on his field investigation, and shall be substituted for the basic stresses given herein. These basic Stresses shall in no case be greater than the maximum given hereinafter.

The effective area of members to be used in the calculations shall be gross area less that portion which has deteriorated due to decay or corrosion. This net area shall be determined in the field. Deductions: for bolt, rivet, and other holes, in accordance with Article 10. 18 of the AASHTO Design Specifications for determining net areas in tension members will be in addition to the loss of area from other causes.

.2 **Structural Steel.** The allowable unit stresses used for determining inventory and operating load capacity depend on the type of steel used in the structural member. When non-specification metals are encountered, coupon testing may be used to determine yield point. When information on specifications of the steel is not available, allowable stresses will be taken from the applicable "Date Built" column of the following tables.

Except where evidence of deterioration or corrosion of the web of a plate girder makes its shear capacity questionable, the spacing of transverse intermediate stiffeners need not be considered in determining its operating rating provided the spacing does not exceed the depth of the web. If, in the judgment of the Engineer, investigation of stiffener spacing is desirable, such an investigation may be based on the load factor design considerations of the AASHTO Specifications.

Unless designated otherwise, values shown in the following Tables 6.6.2.1-1 and 6.6.2.1-2 are allowable inventory and operating stresses respectively for structural steel. Tables 6.6.2.1-3 and 6.6.2.1-4 give the allowable inventory and operating stresses for bolts and rivets.

The allowable combined stresses for steel compression members may be calculated by the provisions of AASHTO.

TABLE 6.6.2.1-1 INVENTORY RATING ALLOWABLE STRESSES (psi)

		DATE BUILT-STEEL UNKNOWN Prior to 1905	1905 to 1936	1936 to 1963	After 1963	Carbon Steel	Silicon Steel Over 2" to 4" incl	Nickel Steel	1-1/8" and Under	Over 1-1/8" to 2" incl
AASHTO Designation [1]						M 94(1961)	M 95(1961)	M 96(1961)		
ASTM Designation [1]						A 7(1967)	A 94(1966)	A 8(1961)	A 94	A 94
Minimum Tensile Strength	F_u	52,000	60,000			60,000	70,000	90,000	75,000	72,000
Minimum Yield Point	F_y	26,000	30,000	33,000	36,000	33,000	45,000	55,000	50,000	47,000
Axial tension in members with no holes for high strength bolts or rivets. Use net section when member has any open holes larger than 1-1/4" diam. such as perforations	$0.55F_y$	14,000	16,000	18,000	20,000	18,000	24,000	30,000	27,000	25,000
	$0.46F_u$				NOT APPLICABLE					
Axial tension in members with holes for high strength bolts or rivets and tension in extreme fiber of rolled shapes, girders, and built-up sections subject to bending (use whichever is smaller)	Gross* Section $0.55F_y$	14,000	16,000	18,000	20,000	18,000	24,000	30,000	27,000	25,000
• When the area of holes deducted for high strength bolts or rivets is more than 15 percent of the gross area, that area in excess of 15 percent shall be deducted from the gross area in determining stress on the gross section. In determining gross section, any open holes larger than 1-1/4" diam. such as perforations shall be deducted.	Net Section $0.50F_u$	26,000	30,000	30,000	30,000	30,000	35,000	45,000	37,500	36,000
	Net Section $0.46F_u$				NOT APPLICABLE					
Axial tension in members without holes. Axial compression, gross section: stiffeners of plate girders. Compression in splice material, gross section	$0.55F_y$	14,000	16,000	18,000	20,000	18,000	24,000	30,000	27,000	25,000
Compression in extreme fibers of rolled shapes, girders and built-up sections, subject to bending, gross section, when compression flange is. (A) Supported laterally its full length by embedment in concrete (B) Partially supported or unsupported[2]	$0.55F_y$	14,000	16,000	18,000	20,000	18,000	24,000	30,000	27,000	25,000

$$F_b = \frac{91 \times 10^6 C_b}{(F.S.)\, S_{xc}} \left(\frac{I_{yc}}{l}\right) \sqrt{0.772 \frac{J}{I_{yc}} + 9.87 \left(\frac{d}{l}\right)^2} \le 0.55F_y$$

$C_b = 1.75 + 1.05\,(M_1/M_2) + 0.3\,(M_1/M_2)^2 \le 2.3$ where M_1 is the smaller and M_2 is the larger end moment in the unbraced segment of the beam; M_1/M_2 is positive when the moments cause reverse curvature and negative when bent in single curvature.

C_b = 1.0 for unbraced cantilevers and for members where the moment within a significant portion of the unbraced segment is greater than or equal to the larger of the segment end moments.

F.S. = Factor of Safety at Inventory Level = 1.82

TABLE 6.6.2.1-1 INVENTORY RATING ALLOWABLE STRESSES (psi) (continued)

		1-1/2" max	1/2" max	Over 2-1/2" to 4" incl	3/4" and under	To 2-1/2" incl (A 514) All thick (A 517)	Ov. 4" to 5" incl (A 588) Ov. 3/4" to 1-1/2" incl
Compression in concentrically loaded columns[h]							
with $C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$		112.8	93.8	79.8	107.0	75.7	111.6
$F_a = \frac{F_y}{F.S.}\left[1 - \frac{\left(\frac{KL}{r}\right)^2 F_y}{4\pi^2 E}\right]$ when $\frac{KL}{r} \leq C_c$		$21{,}230 - 0.83\left(\frac{KL}{r}\right)^2$	$30{,}660 - 1.74\left(\frac{KL}{r}\right)^2$	$42{,}450 - 3.34\left(\frac{KL}{r}\right)^2$	$23{,}580 - 1.03\left(\frac{KL}{r}\right)^2$	$47{,}170 - 4.12\left(\frac{KL}{r}\right)^2$	$21{,}700 - 0.87\left(\frac{KL}{r}\right)^2$
$F_a = \frac{\pi^2 E}{F.S.\left(\frac{KL}{r}\right)^2} = \frac{135{,}008{,}740}{\left(\frac{KL}{r}\right)^2}$ when $KL \geq C_c$ with $F.S. = 2.12$							
Shear in girder webs, gross section		15,000	22,000	30,000	17,000	30,000	15,000
Bearing on milled stiffeners and other steel parts in contact. Stress in extreme fiber of pins	$0.80F_y$	37,000	52,000	72,000	40,000	80,000	37,000
Bearing on pins not subject to rotation		37,000	52,000	72,000	40,000	80,000	37,000
Bearing on pins subject to rotation (such as rockers and hinges)		18,000	26,000	36,000	20,000	40,000	18,000
Shear in pins	$0.40F_y$	18,000	26,000	36,000	20,000	40,000	18,000
Bearing on Power-Driven Rivets and high strength bolts (or as limited by allowable bearing on the Fasteners)	$1.35F_y$	81,000	108,000	142,000	94,500	155,000	90,500

TABLE 6.6.2.1-1 INVENTORY RATING ALLOWABLE STRESSES (psi) (continued)

		1-1/2" max	1" max	Over 5" to 8" incl" (A 588) ov. 1-1/2" to 4" incl	Over 4" to 8" incl
AASHTO Designation [1]					M 188
ASTM Designation [1]		A 572	A 572	A 242, A 440, A 441, A 588, A 572	A 441
Minimum Tensile Strength	F_u	70,000	75,000	63,000	60,000
Minimum Yield Point	F_y	55,000	60,000	42,000	40,000
Axial tension in members with no holes for high strength bolts or rivets. Use net section when member has any open holes larger than 1-1/4" diam. such as perforations	$0.55F_y$	30,000	33,000	23,000	22,000
	$0.46F_u$	NOT APPLICABLE			
Axial tension in members with holes for high strength bolts or rivets and tension in extreme fiber of rolled shapes, girders, and built-up sections subject to bending (use whichever is smaller)	Gross* Section $0.55F_y$	30,000	33,000	23,000	22,000
• When the area of holes deducted for high strength bolts or rivets is more than 15 percent of the gross area, that area in excess of 15 percent shall be deducted from the gross area in determining stress on the gross section. In determining gross section, any open holes larger than 1-1/4" diam. such as perforations shall be deducted.	Net Section $0.50F_u$	35,000	37,500	31,500	30,000
	Net Section $0.46F_u$	NOT APPLICABLE			
Axial tension in members without holes. Axial compression, gross section: stiffeners of plate girders. Compression in splice material, gross section	$0.55F_y$	30,000	33,000	23,000	22,000
Compression in extreme fibers of rolled shapes, girders and built-up sections, subject to bending, gross section, when compression flange is. (A) Supported laterally its full length by embedment in concrete	$0.55F_y$	30,000	33,000	23,000	
(B) Partially supported or unsupported[3]					

$$F_b = \frac{91 \times 10^6 C_b}{(F.S.)\, S_{xc}} \left(\frac{I_{yc}}{l}\right) \sqrt{0.772 \frac{J}{I_{yc}} + 9.87 \left(\frac{d}{l}\right)^2} \leq 0.55F_y$$

TABLE 6.6.2.1-1 INVENTORY RATING ALLOWABLE STRESSES (psi) (continued)

		1-1/2" max	1/2" max	Over 2-1/2" to 4" incl	3/4" and under	To 2-1/2" incl (A 514) All thick (A 517)	Ov. 4" to 5" incl (A 588) Ov. 3/4" to 1-1/2" incl
Compression in concentrically loaded columns[b]							
with $C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$		112.8	93.8	79.8	107.0	75.7	111.6
$F_a = \frac{F_y}{F.S.}\left[1 - \frac{\left(\frac{KL}{r}\right)^2 F_y}{4\pi^2 E}\right]$ when $\frac{KL}{r} \le C_c$		$21{,}230 - 0.83\left(\frac{KL}{r}\right)^2$	$30{,}660 - 1.74\left(\frac{KL}{r}\right)^2$	$42{,}450 - 3.34\left(\frac{KL}{r}\right)^2$	$23{,}580 - 1.03\left(\frac{KL}{r}\right)^2$	$47{,}170 - 4.12\left(\frac{KL}{r}\right)^2$	$21{,}700 - 0.87\left(\frac{KL}{r}\right)^2$
$F_a = \frac{\pi^2 E}{F.S.\left(\frac{KL}{r}\right)^2} = \frac{135{,}008{,}740}{\left(\frac{KL}{r}\right)^2}$ when $KL \ge C_c$ with F.S. = 2.12							
Shear in girder webs, gross section		15,000	22,000	30,000	17,000	30,000	15,000
Bearing on milled stiffeners and other steel parts in contact. Stress in extreme fiber of pins	$0.80F_y$	37,000	52,000	72,000	40,000	80,000	37,000
Bearing on pins not subject to rotation		37,000	52,000	72,000	40,000	80,000	37,000
Bearing on pins subject to rotation (such as rockers and hinges)		18,000	26,000	36,000	20,000	40,000	18,000
Shear in pins	$0.40F_y$	18,000	26,000	36,000	20,000	40,000	18,000
Bearing on Power-Driven Rivets and high strength bolts (or as limited by allowable bearing on the Fasteners)	$1.35F_y$	81,000	108,000	142,000	94,500	155,000	90,500

TABLE 6.6.2.1-1 INVENTORY RATING ALLOWABLE STRESSES (psi) (continued)

		1-1/2" max	1" max	Over 5" to 8" incl" (A 588) ov. 1-1/2" to 4" incl	Over 4" to 8" incl
AASHTO Designation [1]					M 188
ASTM Designation [1]		A 572	A 572	A 242, A 440, A 441, A 588, A 572	A 441
Minimum Tensile Strength	F_u	70,000	75,000	63,000	60,000
Minimum Yield Point	F_y	55,000	60,000	42,000	40,000
Axial tension in members with no holes for high strength bolts or rivets. Use net section when member has any open holes larger than 1-1/4" diam. such as perforations	$0.55F_y$	30,000	33,000	23,000	22,000
	$0.46F_u$	NOT APPLICABLE			
Axial tension in members with holes for high strength bolts or rivets and tension in extreme fiber of rolled shapes, girders, and built-up sections subject to bending (use whichever is smaller)	Gross* Section $0.55F_y$	30,000	33,000	23,000	22,000
	Net Section $0.50F_u$	35,000	37,500	31,500	30,000
• When the area of holes deducted for high strength bolts or rivets is more than 15 percent of the gross area, that area in excess of 15 percent shall be deducted from the gross area in determining stress on the gross section. In determining gross section, any open holes larger than 1-1/4" diam. such as perforations shall be deducted.	Net Section $0.46F_u$	NOT APPLICABLE			
Axial tension in members without holes. Axial compression, gross section: stiffeners of plate girders. Compression in splice material, gross section	$0.55F_y$	30,000	33,000	23,000	22,000
Compression in extreme fibers of rolled shapes, girders and built-up sections, subject to bending, gross section, when compression flange is. (A) Supported laterally its full length by embedment in concrete	$0.55F_y$	30,000	33,000	23,000	
(B) Partially supported or unsupported[2]					

$$F_b = \frac{91 \times 10^6 C_b}{(F.S.)\, S_{xc}} \left(\frac{I_{yc}}{l}\right) \sqrt{0.772 \frac{J}{I_{yc}} + 9.87 \left(\frac{d}{l}\right)^2} \leq 0.55F_y$$

TABLE 6.6.2.1-1 INVENTORY RATING ALLOWABLE STRESSES (psi) (continued)

		1-1/2" max	1" max	ov. 5" to 8" incl* (A 588) ov. 1-1/2" to 4" incl	Over 4" to 8" incl

$C_b = 1.75 + 1.05\,(M_1/M_2) + 0.3\,(M_1/M_2)^2 \leq 2.3$ where M_1 is the smaller and M_2 is the larger end moment in the unbraced segment of the beams; M_1/M_2 is positive when the moments cause reverse curvature and negative when bent in single curvature.

$C_b = 1.0$ for unbraced cantilevers and for members where the moment within a significant portion of the unbraced segment is greater than or equal to the larger of the segment end moments.

F.S. = Factor of Safety at Inventory Level = 1.82

		1-1/2" max	1" max	ov. 5" to 8" incl* (A 588) ov. 1-1/2" to 4" incl	Over 4" to 8" incl
Compression in concentrically loaded columns[3]					
with $C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$		102.0	97.7	116.7	
$F_a = \frac{F_y}{F.S.}\left[1 - \frac{\left(\frac{KL}{r}\right)^2 F_y}{4\pi^2 E}\right]$ when $\frac{KL}{r} \leq C_c$		$25{,}940 - 1.25\left(\frac{KL}{r}\right)^2$	$28{,}300 - 1.48\left(\frac{KL}{r}\right)^2$	$19{,}810 - 0.73\left(\frac{KL}{r}\right)^2$	
$F_a = \frac{\pi^2 E}{F.S.\left(\frac{KL}{r}\right)^2} = \frac{135{,}008{,}740}{\left(\frac{KL}{r}\right)^2}$ when $KL \geq C_c$ with F.S. = 2.12					
Shear in girder webs, gross section		18,000	20,000	14,000	
Bearing on milled stiffeners and other steel parts in contact. Stress in extreme fiber of pins	$0.80F_y$	44,000	48,000	34,000	32,000
Bearing on pins not subject to rotation		44,000	48,000	34,000	32,000
Bearing on pins subject to rotation (such as rockers and hinges)		22,000	24,000	17,000	16,000
Shear in pins	$0.40F_y$	22,000	24,000	17,000	
Bearing on Power-Driven Rivets and high strength bolts (or as limited by allowable bearing on the Fasteners)	$1.35F_u$	94,500	101,000	85,000	81,000

TABLE 6.6.2.1-2 OPERATING RATING ALLOWABLE STRESS (psi)

		DATE BUILT-STEEL UNKNOWN						
		Prior to 1905	1905 to 1936	1936 to 1963	After 1963	Carbon Steel	Silicon Steel Over 2" to 4" incl	Nickel Steel
AASHTO Designation [1]						M 94(1961)	M 95(1961)	M 96(1961)
ASTM Designation [1]						A 7(1967)	A 4(1965)	A 8(1961)
Minimum Tensile Strength	F_u	52,000	60,000			60,000	70,000	90,000
Minimum Yield Point	F_y	26,000	30,000	33,000	36,000	33,000	45,000	55,000
Axial tension in members with no holes for high strength bolts or rivets. Use net section when member has any open holes larger than 1-1/4" diam. such as perforations	$0.75F_y$	19,500	22,500	24,500	27,000	24,500		
	$0.60F_u$	NOT APPLICABLE					33,500	41,000
Axial tension in members with holes for high strength bolts or rivets and tension in extreme fiber of rolled shapes, girders, and built-up sections subject to bending (use whichever is smaller)	Gross* Section $0.75F_y$	19,500	22,500	24,500	27,000	24,500	33,500	41,000
	Net Section $0.67F_u$	35,000	40,000	40,000	40,000	40,000	46,500	60,000
• When the area of holes deducted for high strength bolts or rivets is more than 15 percent of the gross area, that area in excess of 15 percent shall be deducted from the gross area in determining stress on the gross section. In determining gross section, any open holes larger than 1-1/4" diam. such as perforations shall be deducted.	Net Section $0.60F_u$	NOT APPLICABLE						
Axial tension in members without holes. Axial compression, gross section; stiffeners of plate girders. Compression in splice material, gross section	$0.75F_y$	19,500	22,500	24,500	27,000	24,500	33,500	41,000
Compression in extreme fibers of rolled shapes, girders and built-up sections, subject to bending, gross section, when compression flange is. (A) Supported laterally its full length by embedment in concrete	$0.75F_y$	19,500	22,500	24,500	27,000	24,500	33,500	41,000

(B) Partially supported or unsupported[2]

$$F_b = \frac{91 \times 10^6 C_b}{(F.S.)\, S_{xc}} \left(\frac{I_{yc}}{l}\right) \sqrt{0.772 \frac{J}{I_{yc}} + 9.87 \left(\frac{d}{l}\right)^2} \leq 0.75F_y$$

$C_b = 1.75 + 1.05\ (M_1 / M_2) + 0.3\ (M_1 / M_2)^2 \leq 2.3$ where M_1 is the smaller and M_2 is the larger end moment in the unbraced segment of the beams; M_1 / M_2 is positive when the moments cause reverse curvature and negative when bent in single curvature.

$C_b = 1.0$ for unbraced cantilevers and for members where the moment within a significant portion of the unbraced segment is greater than or equal to the larger of the segment end moments.

F.S. = Factor of Safety at Operating Level = 1.34

TABLE 6.6.2.1-2 OPERATING RATING ALLOWABLE STRESS (psi) (continued)

		DATE BUILT-STEEL UNKNOWN				Carbon Steel	Silicon Steel Over 2" to 4" incl	Nickel Steel
		Prior to 1905	1905 to 1936	1936 to 1963	After 1963			
Compression in concentrically loaded columns(3)								
with $C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$		148.4	138.1	131.7	126.1	131.7	112.8	102.0
when $\frac{KL}{r} \geq C_c$								
$F_a = \frac{F_y}{F.S.}\left[1 - \frac{\left(\frac{KL}{r}\right)^2 F_y}{4\pi^2 E}\right]$ when $\frac{KL}{r} \geq C_c$		$15{,}390 - 0.35\left(\frac{KL}{r}\right)^2$	$17{,}650 - 0.46\left(\frac{KL}{r}\right)^2$	$19{,}410 - 0.56\left(\frac{KL}{r}\right)^2$	$21{,}180 - 0.67\left(\frac{KL}{r}\right)^2$	$19{,}410 - 0.56\left(\frac{KL}{r}\right)^2$	$26{,}470 - 1.04\left(\frac{KL}{r}\right)^2$	$32{,}350 - 1.55\left(\frac{KL}{r}\right)^2$
$F_a = \frac{\pi^2 E}{F.S.\left(\frac{KL}{r}\right)^2} = \frac{168{,}363{,}840}{\left(\frac{KL}{r}\right)^2}$ with F.S. = 1.70								
Shear in girder webs, gross section	$0.45F_y$	11,500	13,500	15,000	16,000	15,000	20,000	24,500
Bearing on milled stiffeners and other steel parts in contact. Stress in extreme fiber of pins	$0.90F_y$	23,000	27,000	29,500	32,000	29,500	40,500	49,500
Bearing on pins not subject to rotation	$0.90F_y$	23,000	27,000	29,500	32,000	29,500	40,500	49,500
Bearing on pins subject to rotation (such as rockers and hinges)	$0.55F_y$	14,000	16,500	18,000	19,500	18,000	24,500	30,000
Shear in pins	$0.55F_y$	14,000	16,500	18,000	19,500	18,000	24,500	30,000
Bearing on Power-Driven Rivets and high strength bolts (or as limited by allowable bearing on the Fasteners)	$1.85F_y$	96,000	111,000	111,000	111,000	111,000	129,500	166,500

(1) Number in parenthesis represents the last year these specifications were printed

(2) For the use of larger C_b values, see *Structural Stability Research Council Guide to Stability Design Criteria for Metal Structures*, 3rd Ed., pg. 135. If cover plates are used, the allowable static stress at the point of theoretical cutoff shall be as determined by the formula.

l = length in inches, of unsupported flange between lateral connections, knee braces, or other points of support

I_{yc} = moment of inertia of compression flange about the vertical axis in the plane of the web, in.^{4}

d = depth of girder, in.

$J = \frac{[(bt^3)_c + (bt^3)_t + Dt_w^3]}{3}$, in.^{4}, where b and t represent the flange width and thickness of the compression and tension flange, D is the web depth, and t_w is the web thickness.

S_{xc} = section modulus with respect to the compression flange, in^3.

(3) E = modulus of elasticity of steel

r = governing radius of gyration

L = actual unbraced length

K = effective length factor

Note: The formulas do not apply to members with variable moment of inertia.

TABLE 6.6.2.1-2 OPERATING RATING ALLOWABLE STRESS (psi) (continued)

		8" and Under	1-1/8" and Under	Over 1-1/8" to 3" incl	1-1/2" max	1/2" max	Over 2-1/2" to 4" incl	3/4" and under 4" and under (A 588)
AASHTO Designation [1]								
ASTM Designation [1]		A 36	A 94	A 94	A 572	A 572	A 514	A 242, A 440, A 441, A 588, A 572
Minimum Tensile Strength	F_u	58,000	75,000	72,000	60,000	80,000	105,000	70,000
Minimum Yield Point	F_y	36,000	50,000	47,000	45,000	65,000	90,000	50,000
Axial tension in members with no holes for high strength bolts or rivets. Use net section when member has any open holes larger than 1-1/4" diam. such as perforations	$0.75F_y$ $0.60F_u$	27,000 NOT APPLICABLE	37,500	35,000	33,500	48,500	N.A. 63,000	37,500 N.A.
Axial tension in members with holes for high strength bolts or rivets and tension in extreme fiber of rolled shapes, girders, and built-up sections subject to bending (use whichever is smaller)	Gross* Section $0.75F_y$	27,000	37,500	35,000	33,500	48,500	67,500	37,500
	Net Section $0.67F_y$	38,000	50,000	48,000	40,000	53,000	N.A.	46,500
	Net Section $0.60F_u$	NOT APPLICABLE					63,000	N.A.
Axial tension in members without holes. Axial compression, gross section: stiffeners of plate girders. Compression in splice material, gross section	$0.75F_y$	27,000	37,500	35,000	33,500	48,500	67,500	37,500
Compression in extreme fibers of rolled shapes, girders and built-up sections, subject to bending, gross section, when compression flange is: (A) Supported laterally its full length by embedment in concrete	$0.75F_y$	27,000	37,500	35,000	33,500	48,500	67,500	37,500

* When the area of holes deducted for high strength bolts or rivets is more than 15 percent of the gross area, that area in excess of 15 percent shall be deducted from the gross area in determining stress on the gross section. In determining gross section, any open holes larger than 1-1/4" diam. such as perforations shall be deducted.

(B) Partially supported or unsupported[1]

$$F_b = \frac{91 \times 10^6 C_b}{(F.S.)\, S_{xc}} \left(\frac{I_{yc}}{l}\right) \sqrt{0.772 \frac{J}{I_{yc}} + 9.87 \left(\frac{d}{l}\right)} \leq 0.75F_y$$

TABLE 6.6.2.1-2 OPERATING RATING ALLOWABLE STRESS (psi) (continued)

		8" and Under	1-1/8" and Under	Over 1-1/8" to 2" incl	1-1/2" max	1/2" max	Over 2-1/2" to 4" incl	3/4" and under 4" and under (A 588)
$C_b = 1.75 + 1.05\,(M_1/M_2) + 0.3\,(M_1/M_2)^2 \leq 2.3$ where M_1 is the smaller and M_2 is the larger end moment in the unbraced segment of the beams; M_1/M_2 is positive when the moments cause reverse curvature and negative when bent in single curvature. C_b = 1.0 for unbraced cantilevers and for members where the moment within a significant portion of the unbraced segment is greater than or equal to the larger of the segment end moments. F.S. = Factor of Safety at Operating Level = 1.34								
Compression in concentrically loaded columns[1]								
with $C_c = \sqrt{\dfrac{2\pi^2 E}{F_y}}$		126.1	107.0	110.4	112.8.	93.8	79.8.	107.0
when $\dfrac{KL}{r} \leq C_c$								
$F_a = \dfrac{F_y}{F.S.}\left[1 - \dfrac{\left(\dfrac{KL}{r}\right)^2 F_y}{4\pi^2 E}\right]$ when $\dfrac{KL}{r} \geq C_c$		$21{,}180 - 0.67\left(\dfrac{KL}{r}\right)^2$	$29{,}410 - 1.28\left(\dfrac{KL}{r}\right)^2$	$27{,}650 - 1.13\left(\dfrac{KL}{r}\right)^2$	$26{,}470 - 1.04\left(\dfrac{KL}{r}\right)^2$	$38{,}240 - 2.17\left(\dfrac{KL}{r}\right)^2$	$52{,}940 - 4.16\left(\dfrac{KL}{r}\right)^2$	$29{,}410 - 1.28\left(\dfrac{KL}{r}\right)^2$
$F_a = \dfrac{\pi^2 E}{F.S.\left(\dfrac{KL}{r}\right)^2} = \dfrac{168{,}363{,}840}{\left(\dfrac{KL}{r}\right)^2}$ with F.S. = 1.70								
Shear in girder webs, gross section	$0.45F_y$	16,000	22,500	21,000	20,000	29,000	40,500	22,500
Bearing on milled stiffeners and other steel parts in contact. Stress in extreme fiber of pins	$0.90F_y$	32,000	45,000	42,000	40,500	58,500	81,000	45,000
Bearing on pins not subject to rotation	$0.90F_y$	32,000	45,000	42,000	40,500	58,500	81,000	45,000
Bearing on pins subject to rotation (such as rockers and hinges)	$0.55F_y$	19,500	27,500	25,500	24,500	35,500	49,500	27,500
Shear in pins	$0.55F_y$	19,500	27,500	25,500	24,500	35,500	49,500	27,500
Bearing on Power-Driven Rivets and high strength bolts (or as limited by allowable bearing on the Fasteners)	$1.85F_u$	107,000	138,500	133,000	171,000	148,000	194,000	129,500

TABLE 6.6.2.1-2 OPERATING RATING ALLOWABLE STRESS (psi) (continued)

		To 2-1/2" incl (A 514) All thick (A 517)	Ov. 4" to 5" incl (A 588) Ov. 3/4" to 1-1/2" incl	1-1/2" max	1" max	Ov. 5" to 8" incl (A 588) Ov. 1-1/2" to 4" incl	Over 4" to 8" incl
AASHTO Designation [1]							
ASTM Designation [1]		A 514-A 517	A 242, A 440, A 441, A 588	A 572	A 572	A 242, A 440, A 441, A 588, A 572	A 441
Minimum Tensile Strength	F_u	115,000	67,000	70,000	75,000	63,000	69,000
Minimum Yield Point	F_y	100,000	46,000	55,000	60,000	42,000	40,000
Axial tension in members with no holes for high strength bolts or rivets. Use net section when member has any open holes larger than 1-1/4" diam. such as perforations	$0.75F_y$	75,000	34,500	41,000	45,000		30,000
	$0.60F_u$	69,000	NOT APPLICABLE				
Axial tension in members with holes for high strength bolts or rivets and tension in extreme fiber of rolled shapes, girders, and built-up sections subject to bending * When the area of holes deducted for high strength bolts or rivets is more than 15 percent of the gross area, that area in excess of 15 percent shall be deducted from the gross area in determining stress on the gross section. In determining gross section, any open holes larger than 1-1/4" diam. such as perforations shall be deducted. — use whichever is smaller	Gross* Section $0.75F_y$	75,000	34,500	41,000	45,000	31,500	30,000
	Net Section $0.67F_u$	N.A.	44,500	46,500	50,000	42,000	40,000
	Net Section $0.60F_u$	69,000	NOT APPLICABLE				
Axial tension in members without holes. Axial compression, gross section: stiffeners of plate girders. Compression in splice material, gross section	$0.75F_y$	75,000	34,500	41,000	45,000	31,500	30,000
Compression in extreme fibers of rolled shapes, girders and built-up sections, subject to bending, gross section, when compression flange is. (A) Supported laterally its full length by embedment in concrete	$0.75F_y$	75,000	34,500	41,000	45,000	31,500	

(B) Partially supported or unsupported[2]

$$F_b = \frac{91 \times 10^6 C_b}{(F.S.)\, S_{xc}} \left(\frac{I_{yc}}{l}\right) \sqrt{0.772 \frac{J}{I_{yc}} + 9.87 \left(\frac{d}{l}\right)^2} \leq 0.75F_y$$

TABLE 6.6.2.1-2 OPERATING RATING ALLOWABLE STRESS (psi) (continued)

		To 2-1/2" incl (A 511) All thick (A 517)	Ov. 4" to 5" incl (A 588) Ov. 3/4" to 1-1/2" incl	1-1/2" max	1" max	Ov. 5" to 8" incl (A 588) Ov. 1-1/2" to 4" incl	Over 4" to 8" incl
$C_b = 1.75 + 1.05\,(M_1/M_2) + 0.3\,(M_1/M_2)^2 \le 2.3$ where M_1 is the smaller and M_2 is the larger end moment in the unbraced segment of the beams; M_1/M_2 is positive when the moments cause reverse curvature and negative when bent in single curvature. $C_b = 1.0$ for unbraced cantilevers and for members where the moment within a significant portion of the unbraced segment is greater than or equal to the larger of the segment end moments. F.S. = Factor of Safety at Operating Level = 1.34							
Compression in concentrically loaded columns[h]							
with $C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$		75.7	111.6	102.0	97.7	116.7	
with $\frac{KL}{r} \le C_c$ $F_a = \frac{F_y}{F.S.}\left[1 - \frac{\left(\frac{KL}{r}\right)^2 F_y}{4\pi^2 E}\right]$ when $\frac{KL}{r} \ge C_c$		$58{,}820 - 5.14\left(\frac{KL}{r}\right)^2$	$27{,}060 - 1.09\left(\frac{KL}{r}\right)^2$	$32{,}350 - 1.55\left(\frac{KL}{r}\right)^2$	$35{,}290 - 1.85\left(\frac{KL}{r}\right)^2$	$24{,}710 - 0.91\left(\frac{KL}{r}\right)^2$	
$F_a = \frac{\pi^2 E}{F.S.\left(\frac{KL}{r}\right)^2} = \frac{108{,}363{,}840}{\left(\frac{KL}{r}\right)^2}$ with F.S. = 1.70							
Shear in girder webs, gross section	$0.45F_y$	45,000	20,500	24,500	27,000	18,500	18,000
Bearing on milled stiffeners and other steel parts in contact. Stress in extreme fiber of pins	$0.90F_y$	90,000	41,000	49,500	54,000	37,500	36,000
Bearing on pins not subject to rotation	$0.90F_y$	90,000	41,000	49,500	54,000	37,500	36,000
Bearing on pins subject to rotation (such as rockers and hinges)	$0.55F_y$	55,000	25,000	30,000	33,000	23,000	22,000
Shear in pins	$0.55F_y$	55,000	25,000	30,000	33,000	23,000	22,000
Bearing on Power-Driven Rivets and high strength bolts (or as limited by allowable bearing on the Fasteners)	$1.85F_y$	213,000	124,000	129,500	138,500	116,500	111,000

TABLE 6.6.2.1-3 Allowable Inventory and Operating Stresses For Low Carbon Steel Bolts and Power Driven Rivets (PSI)

Type of Fastener	Rating Level	Tension	Bearing	Shear: Bearing Type Connection
(A) Low Carbon Steel Bolts: Turned Bolts (ASTM A 307) and Ribbed Bolts[1][2]	INV	18,000	20,000	11,000[3]
	OPR	24,500	27,000	15,000[3]
(B) Power Driven Rivets (rivets driven by pneumatically or electrically operated hammers are considered power driven) Structural Steel Rivet (ASTM A 502 Grade 1 or ASTM A 141)	INV	—	40,000	13,500
	OPR	—	54,500	18,000
Structural Steel Rivet (High Strength) (ASTM A 502 Grade 2)	INV	—	40,000	20,000
	OPR	—	54,500	27,000

(1) The AASHTO Design Specifications indicate that ASTM A 307 bolts shall not be used in connections subject to Fatigue.
(2) Based on nominal diameter of bolt.
(3) Threads permitted in the shear plane.

TABLE 6.6.2.1-4 Allowable Inventory and Operating Stresses for High Strength Bolts in ksi[a]

Load Condition	Hole Type	Rating Level	AASHTO M 164[e] (ASTM A 325) Bolts	AASHTO M 253 (ASTM A 490) Bolts
Applied Tension (T)	Standard, oversize or slotted	INV	38[f]	47
		OPR	52[f]	64
Shear (F_v): Slip-critical connection[b]	Standard	INV	15[f]	19
		OPR	20[f]	26
	Oversize or short-slotted loaded in any direction	INV	13[f]	16
		OPR	18[f]	22
	Long-slotted Load transverse	INV	11[f]	13
		OPR	15[f]	18
	Long-slotted Load parallel	INV	9[f]	11
		OPR	12[f]	15
Shear (F_v): Bearing-type connection[c]				
Threads in any shear plane	Standard or slotted	INV	19[f]	24
		OPR	26[f]	33
No threads in shear plane	Standard or slotted	INV	24[f]	30
		OPR	33[f]	41
Bearing (f_b) on connected material	Standard, oversize or short-slotted loaded in any direction	INV	$\frac{0.5 L_c F_u}{d} \leq F_u$[d]	
		OPR	$\frac{0.7 L_c F_u}{d} \leq 1.4 F_u$[d]	
	Long-slotted Load parallel	INV	$\frac{0.5 L_c F_u}{d} \leq F_u$[d]	
		OPR	$\frac{0.7 L_c F_u}{d} \leq 1.4 F_u$[d]	
	Long-slotted Load transverse	INV	$\frac{0.4 L_c F_u}{d} \leq 0.8 F_u$[d]	
		OPR	$\frac{0.55 L_c F_u}{d} \leq 1.1 F_u$[d]	

a The tabulated stresses, except for bearing stress, apply to the nominal area of bolts used in any grade of steel.

b Applicable for contact surfaces with clean mill scale (slip coefficient 0.33).

c In bearing-type connections whose length between extreme fasteners in each of the spliced parts measured parallel to the line of an axial force exceeds 50 inches (1.27 m), tabulated value shall be reduced by 20 percent.

d L_c is equal to the clear distance between the holes or between the hole and the edge of the material in the direction of applied bearing force, in.; F_u is the specified minimum tensile strength of the connected material; d is the nominal diameter of the bolt, in.

e AASHTO M 164 (ASTM A 325) and AASHTO M 253 (ASTM A 490) high-strength bolts are available in three types, designated as types 1, 2 or 3.

f The tensile strength of M 164 (A 325) bolts decreases for diameters greater than 1 inch. The values listed are for bolts up to 1-inch diameter. The values shall be multiplied by 0.875 for diameters greater than 1 inch.

H. 3 **Wrought Iron.** Allowable maximum unit stress (psi) in wrought iron for tension and bending.

Inventory	14,600 psi
Operating	20,000 psi

Where possible coupon tests should be performed to confirm material properties used in the rating. The rating summary as appropriate shall clearly indicate capacities for both stress levels.

H. 4 **Reinforcing Steel.** The following are the allowable unit stresses in tension for reinforcing steel. These will ordinarily be used without reduction when the condition of the steel is unknown:

	Inventory Rating	**Operating Rating**
Structural or unknown grade prior to 1954	18,000 psi	25,000 psi
Grade 40 billet, inter mediate, or unknown grade (after 1954)	20,000	28,000
Grade 50 rail or hard	20,000	32,500
Grade 60	24,000	36,000

H. 5 **Concrete.** Unless there is a mix formula given on the plans, concrete for superstructures shall be assumed as 2000# concrete before, 1931 and 3000# concrete for 1931 on. If a mix is given, the strengths shall be taken from the 1916 Joint Committee Report (see table below). Allowable inventory and operating stresses shall respectively be .4 and .55 of F'c.,

Mix = 1: 1:2	1:11/2:3	1:2:4	1:2.5:5	1 :3 :6
F'c = 3000 psi	2500	2000	1600	1300

The use of intermediate grade reinforcing steel as shown in the AASHTO "Manual for Maintenance Inspection of Bridges," began in 1952.

H. 6 Prestressed Concrete. The load rating of prestressed concrete members shall be in accordance with AASHTO Manual for Condition Evaluation of Structures Section 6.6.3.3.

H. 7 **Timber.** Determining allowable stresses for timber in existing bridges will require sound judgment on the part of Engineer making the field investigation.

1. Inventory Stress
The Inventory unit stresses should be equal to the allowable stresses for stress-grade lumber given in AASHTO Design Specifications.

Allowable Inventory unit stresses for timber columns should be in accordance with the applicable provisions of the AASHTO Design Specifications.

2. Operating Stress

The maximum allowable operating unit stresses will not exceed 1.33 times the allowable stresses for stress-grade lumber given in the current AASHTO Design Specifications. Reduction from the maximum allowable stress will depend upon the grade and condition of the timber and shall be determined at the time of the inspection.

Allowable operating stress in pounds per square inch of cross-sectional area of simple solid columns should be determined by the following formulae but the allowable operating stress shall not exceed 1.33 times the values for compression parallel to grain given in the design stress table of the AASHTO Design Specifications.

$$P / A = \frac{4.813E}{(l / r)^2}$$

in which P = total load in pounds.

A = cross-sectional area in square inches.

E = modulus of elasticity.

ℓ = unsupported overall length, in inches, between points of lateral support of simple columns.

r = least radius of gyration of the section.

For columns of square or rectangular cross-section this formula becomes:

$$P / A = \frac{0.40E}{(l / d)^2}$$

in which d = dimension in inches of the face under consideration.

The above formula applies to long columns with (l/d) over 11, but not greater than 50.

For short columns, (l/d) not over 11, use the allowable design unit stress in compression parallel to grain times 1.33 for the grade of timber used.

I. FATIGUE CONSIDERATIONS FOR STEEL STRUCTURES

I. 1 General

(a) The evaluation of the safe remaining life of steel bridges may be required when planning retrofit, rehabilitation or replacement schedules or establishing limitations on vehicle weights or speed restrictions. Remaining life is also a consideration in an assessment of critical redundant or nonredundant details for inspection and fracture control. When necessary as outlined above an evaluation shall be performed for revenue vehicles for those members, which are controlled by allowable stress range for fatigue from Table 3. For stress category, see Table 4 and Figure B.

(b) Number of Constant Stress Cycles shall be assumed as over 2,000,000.

(c) The stress range Fsr is defined as the algebraic difference between the maximum and minimum calculated stress due to live load, impact load, and centrifugal load. If live load impact load and centrifugal load result in compressive stresses and the dead load stress is compression, fatigue need not be considered.

(d) For welded or rolled steel members and welded and high strength bolted connections subject to repeated fluctuations of stress, fatigue requirements of Table 3 shall be considered.

(e) For members with riveted or bolted connections with low slip resistance subject to repeated stress fluctuations, the requirements of Category D Table 3 shall be considered. Where the Engineer can verify that the fasteners are tight and have developed a normal level of clamping force, fatigue Category C may be used.

(f) Riveted and bolted connections and members that do not satisfy the requirements of Paragraph (e) above may have these requirements waived at the discretion of the Engineer if the connections or members will retain their structural adequacy if one of the elements cracks. The connection, member, or span must hove adequate capacity to carry the redistributed load and the frequency of inspections which will permit timely discovery of any local failure and need for corrective action.

(g) For eyebars and pinplates subject to repeated fluctuations of stress, the requirements of fatigue Category E of for the nominal stresses acting on the net section of the eyebar head or pinplate, shall be considered.

(h) For main load carrying components subjected to tensile stresses that may be considered nonredundant load path members (that is, where failure of single element could cause collapse) shall be evaluated for the allowable stress ranges indicated in Table 3 or Nonredundant Load Path Structures. Examples of nonredundant load path members are flange and web plates in one or two girder bridges, main one-element truss members, hanger plates, and caps at single or two-column bents.

(i) When necessary the Engineer may determine the number of actual cycles from historic records and as appropriate adjust the allowable stress range. Field inspection shall note fracture critical members, redundancy, and fatigue prone details especially those in Category D or lower.

Redundant Load Path Structures*
Allowable Range of Stress, F_{sr} (ksi)[a]

Stress Category See Table 4	For over 2,000,000 Cycles
A	24 (16)[d]
B	16
B'	12
C	10 (12)[b]
D	7
E	4.5
E'	2.6
F	8

Nonredundant Load Path Structures
Allowable Range of Stress, F_{sr} (ksi)[a]

Stress Category See Table 4	For over 2,000,000 Cycles
A	24 (16)[d]
B	16
B'	11
C	9 (11)[b]
D	5
E[c]	2.3
E'	1.3
F	6

Table 3 Allowable Fatigue Stress Range (ksi)

*Structure types with multi-load paths where a single fracture in a member cannot lead to the collapse. For example, a simply supported single-span, multi-beam bridge or a multi-element eye bar truss member has redundant load paths.

[a] The range of stress is defined as the algebraic difference between the maximum stress and the minimum stress. Tension stress is considered to have the opposite algebraic sign from compression stress.

[b] For transverse stiffener welds on girder webs or flanges.

[c] Partial length welded cover plates shall not be used on flanges more than 0.8 inches thick for nonredundant load path structures.

[d] For unpainted weathering steel, A709, all grades when used in conformance with the FHWA *Technical Advisory on Uncoated Weathering Steel in Structures*, dated October 3, 1989.

General Condition	Situation	Kind of Stress	Stress Category See Table 3	Illustrative Example See Figure B
Plain Member	Base metal with rolled or cleaned surface. Flame-cut edges with ANSI smoothness of 1,000 or less.	T or Rev[A]	A	1,2
Built-Up Members	Base metal and weld metal in members of built-up plates or shapes (without attachments) connected by continuous full penetration groove welds (with backing bars removed) or by continuous fillet welds parallel to the direction of applied stress.	T or Rev	B	3,4,5,7
	Base metal and weld metal in members of built-up plates or shapes (without attachments) connected by continuous full penetration groove welds with backing bars not removed, or by continuous partial penetration groove welds parallel to the direction of applied stress.	T or Rev	B'	3,4,5,7
	Calculated flexural stress at the toe of transverse stiffener welds on girder webs or flanges.	T or Rev	C	6
	Base metal at ends of partial length welded coverplates with high-strength bolted slip-critical end connections. (See Note f.)	T or Rev	B	22
	Base metal at ends of partial length welded coverplates narrower than the flange having square or tapered ends, with or without welds across the ends, or wider than flange with welds across the ends:			
	(a) Flange thickness $\leq$ 0.8 in.	T or Rev	E	7
	(b) Flange thickness $>$ 0.8 in.	T or Rev	E'	7
	Base metal at ends of partial length welded coverplates wider than the flange without welds across the ends.	T or Rev	E'	7
Groove Welded Connections	Base metal and weld metal in or adjacent to full penetration groove weld splices of rolled or welded sections having similar profiles when welds are ground flush with grinding in the direction of applied stress and weld soundness established by nondestructive inspection.	T or Rev	B	8,10
	Base metal and weld metal in or adjacent to full penetration groove weld splices with 2 ft radius transitions in width, when welds are ground flush with grinding in the direction of applied stress and weld soundness established by nondestructive inspection.	T or Rev	B	13
	Base metal and weld metal in or adjacent to full penetration groove weld splices at transitions in width or thickness, with welds ground to provide slopes no steeper than 1 to 2½, with grinding in the direction of the applied stress, and weld soundness established by nondestructive inspection:			
	(a) AASHTO M 270 Grades 100/100W (ASTM A 709) base metal	T or Rev	B'	11,12
	(b) Other base metals	T or Rev	B	11,12
	Base metal and weld metal in or adjacent to full penetration groove weld splices, with or without transitions having slopes no greater than 1 to 2½, when the reinforcement is not removed and weld soundness is established by nondestructive inspection.	T or Rev	C	8,10,11,12
Groove Welded Attachments—Longitudinally Loaded[b]	Base metal adjacent to details attached by full or partial penetration groove welds when the detail length, L, in the direction of stress, is less than 2 in.	T or Rev	C	6,15
	Base metal adjacent to details attached by full or partial penetration groove welds when the detail length, L, in the direction of stress, is between 2 in. and 12 times the plate thickness but less than 4 in.	T or Rev	D	15

Table 4 Construction Details

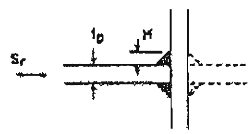
General Condition	Situation	Kind of Stress	Stress Category See Table 3	Illustrative Example See Figure B
	Base metal adjacent to details attached by full or partial penetration groove welds when the detail length, L, in the direction of stress, is greater than 12 times the plate thickness or greater than 4 in.:			
	(a) Detail thickness < 1.0 in.	T or Rev	E	15
	(b) Detail thickness ≥ 1.0 in.	T or Rev	E′	15
	Base metal adjacent to details attached by full or partial penetration groove welds with a transition radius, R, regardless of the detail length:			
	—With the end welds ground smooth	T or Rev		16
	(a) Transition radius ≥ 24 in.		B	
	(b) 24 in. > Transition radius ≥ 6 in.		C	
	(c) 6 in. > Transition radius ≥ 2 in.		D	
	(d) 2 in. > Transition radius ≥ 0 in.		E	
	—For all transition radii without end welds ground smooth.	T or Rev	E	16
Groove welded Attachments—Transversely Loaded[b,c]	Detail base metal attached by full penetration groove welds with a transition radius, R, regardless of the detail length and with weld soundness transverse to the direction of stress established by nondestructive inspection:			
	—With equal plate thickness and reinforcement removed	T or Rev		16
	(a) Transition radius ≥ 24 in.		B	
	(b) 24 in. > Transition radius ≥ 6 in.		C	
	(c) 6 in. > Transition radius ≥ 2 in.		D	
	(d) 2 in. > Transition radius ≥ 0 in.		E	
	—With equal plate thickness and reinforcement not removed	T or Rev		16
	(a) Transition radius ≥ 6 in.		C	
	(b) 6 in. > Transition radius ≥ 2 in.		D	
	(c) 2 in. > Transition radius ≥ 0 in.		E	
	—With unequal plate thickness and reinforcement removed	T or Rev		16
	(a) Transition radius ≥ 2 in.		D	
	(b) 2 in. > Transition radius ≥ 0 in.		E	
	—For all transition radii with unequal plate thickness and reinforcement not removed.	T or Rev	E	16
Fillet Welded Connections	Base metal at details connected with transversely loaded welds, with the welds perpendicular to the direction of stress:			
	(a) Detail thickness ≤ 0.5 in.	T or Rev	C	14
	(b) Detail thickness > 0.5 in.	T or Rev	See Note[d]	
	Base metal at intermittent fillet welds.	T or Rev	E	—
	Shear stress on throat of fillet welds.	Shear	F	9
Fillet Welded Attachments—Longitudinally Loaded[b,c,e]	Base metal adjacent to details attached by fillet welds with length, L, in the direction of stress, is less than 2 in. and stud-type shear connectors.	T or Rev	C	15,17,18,20
	Base metal adjacent to details attached by fillet welds with length, L, in the direction of stress, between 2 in. and 12 times the plate thickness but less than 4 in.	T or Rev	D	15,17
	Base metal adjacent to details attached by fillet welds with length, L, in the direction of stress greater than 12 times the plate thickness or greater than 4 in.:			
	(a) Detail thickness < 1.0 in.	T or Rev	E	7,9,15,17
	(b) Detail thickness ≥ 1.0 in.	T or Rev	E′	7,9,15

Table 4 (Cont'd)

General Condition	Situation	Kind of Stress	Stress Category (See Table 3)	Illustrative Example See Figure B
	Base metal adjacent to details attached by fillet welds with a transition radius, R, regardless of the detail length:			
	—With the end welds ground smooth (a) Transition radius ≥ 2 in. (b) 2 in. > Transition radius ≥ 0 in.	T or Rev	 D E	16
	—For all transition radii without the end welds ground smooth.	T or Rev	E	16
Fillet Welded Attachments—Transversely Loaded with the Weld in the Direction of Principal Stress[b,e]	Detail base metal attached by fillet welds with a transition radius, R, regardless of the detail length (shear stress on the throat of fillet welds governed by Category F):			
	—With the end welds ground smooth (a) Transition radius ≥ 2 in. (b) 2 in. > Transition radius ≥ 0 in.	T or Rev	 D E	16
	—For all transition radii without the end welds ground smooth.	T or Rev	E	16
Mechanically Fastened Connections	Base metal at gross section of high-strength bolted slip resistant connections, except axially loaded joints which induce out-of-plane bending in connecting materials.	T or Rev	B	21
	Base metal at net section of high-strength bolted bearing-type connections.	T or Rev	B	21
	Base metal at net section of riveted connections.	T or Rev	D	21
Eyebar or Pin Plates	Base metal at the net section of eyebar head, or pin plate	T	E	23, 24
	Base metal in the shank of eyebars, or through the gross section of pin plates with: (a) rolled or smoothly ground surfaces (b) flame-cut edges	 T T	 A B	 23, 24 23, 24

[a] "T" signifies range in tensile stress only, "Rev" signifies a range of stress involving both tension and compression during a stress cycle.
[b] "Longitudinally Loaded" signifies direction of applied stress is parallel to the longitudinal axis of the weld. "Transversely Loaded" signifies direction of applied stress is perpendicular to the longitudinal axis of the weld.
[c] Transversely loaded partial penetration groove welds are prohibited.
[d] Allowable fatigue stress range on throat of fillet welds transversely loaded is a function of the effective throat and plate thickness. (See Frank and Fisher, Journal of the Structural Division, ASCE, Vol. 105, No. ST9, Sept. 1979.)

$$S_r = S_r^C \left(\frac{0.06 + 0.79 H/t_p}{1.1 t_p^{1/6}} \right)$$



where S_r^C is equal to the allowable stress range for Category C given in Table 10.3.1A. This assumes no penetration at the weld root.

[e] Gusset plates attached to girder flange surfaces with only transverse fillet welds are prohibited.

[f] See Wattar, Albrecht and Sahli, Journal of Structural Engineering, ASCE, Vol. III, No. 6, June 1985, pp. 1235–1249.

Table 4 (Cont'd)

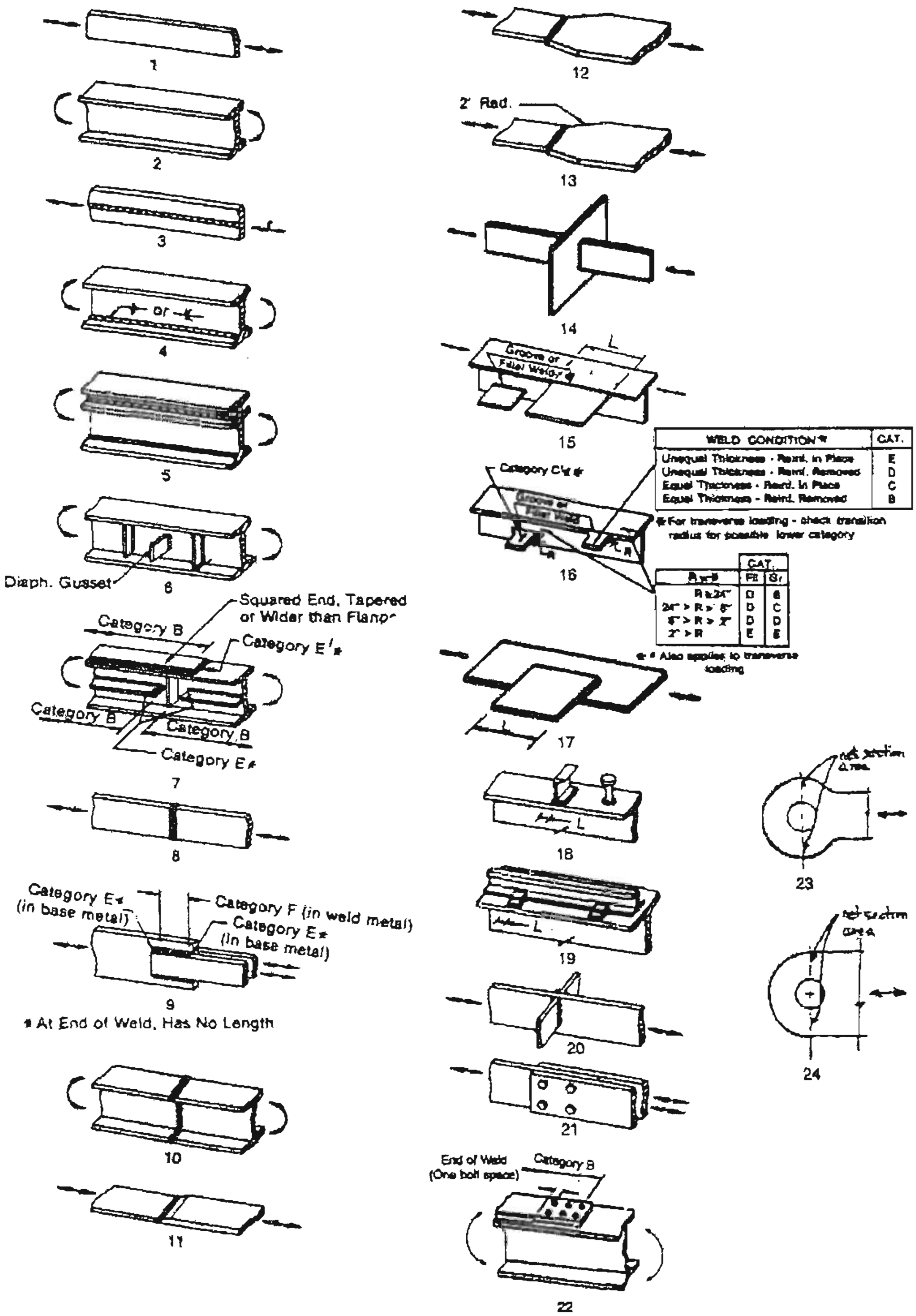


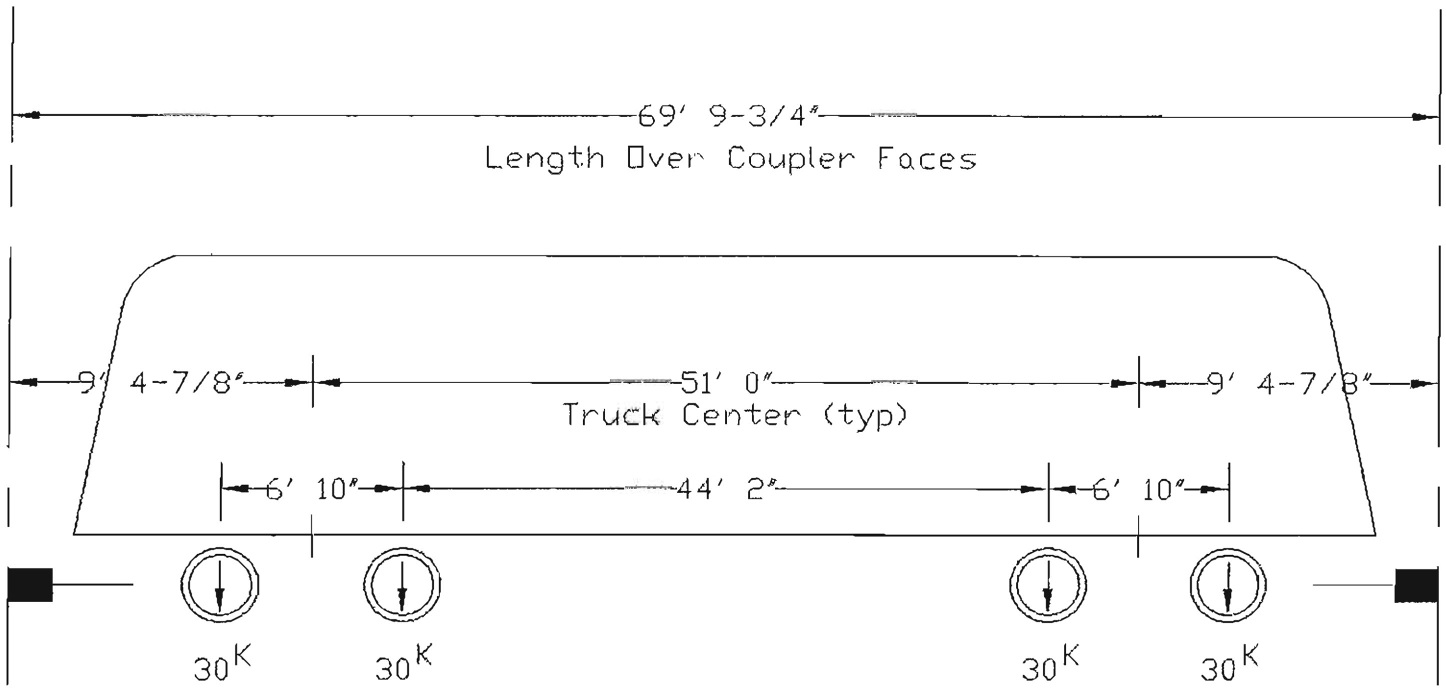
Figure A Fatigue Categories

APPENDIX A

REVENUE CAR LOAD TABLES

NOTE:

The following moment, shear and reaction tables are provided only as a guide. See Figure A and following sketches for further description of Revenue Vehicles. Each individual case should be verified by the rating engineer.



#3 RED LINE RAPID TRANSIT CAR

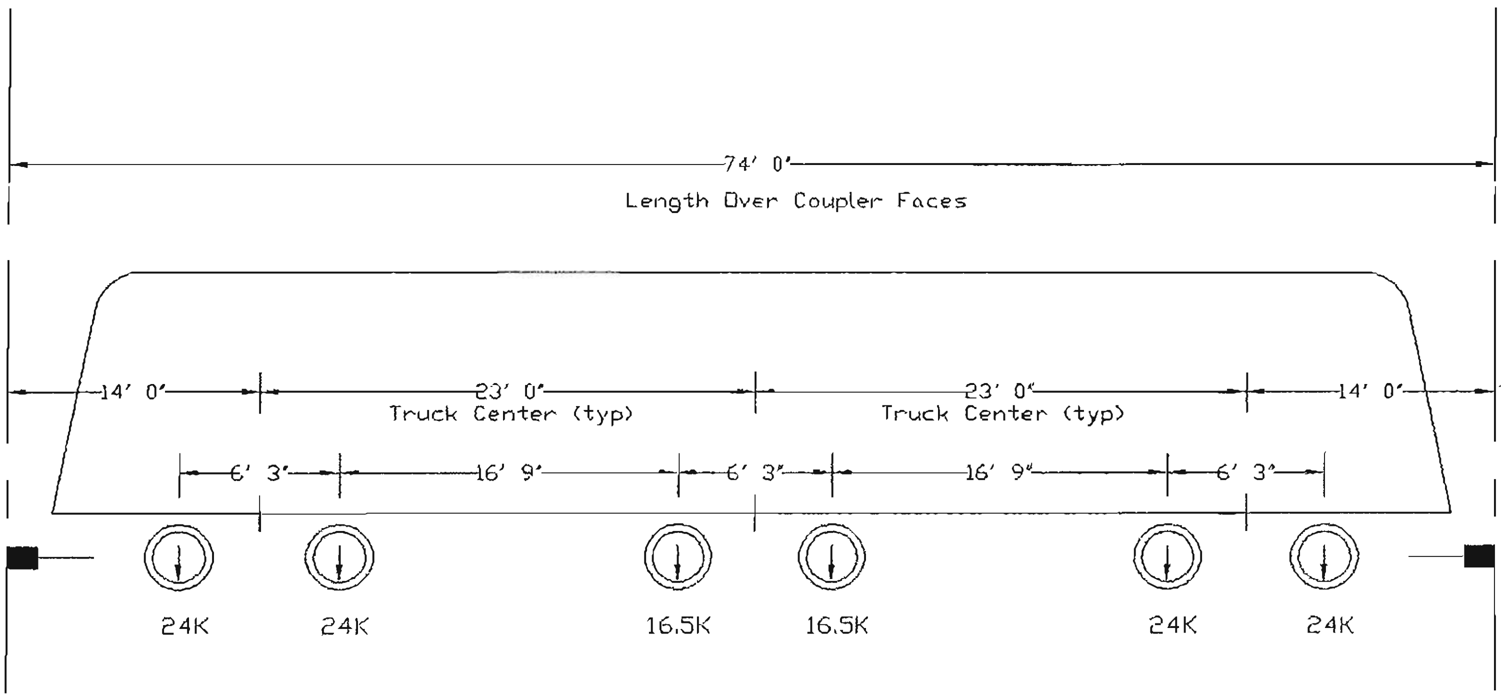
LOADINGS:

Empty Vehicle = 76,885 lbs

Max. Crush Load = 42,935 lbs

Actual Weight of Fully Loaded Car = 119,820 lbs

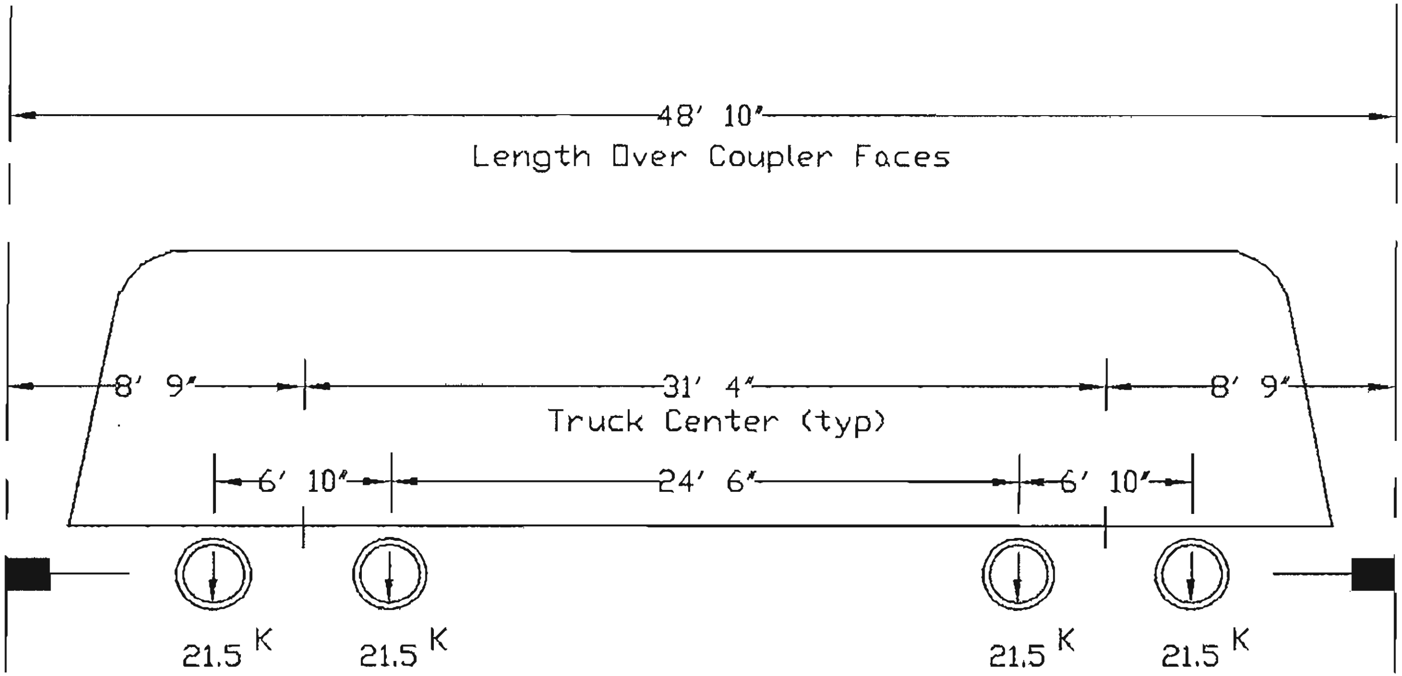
Rating Load for Fully Loaded Car = 120,000 lbs



#7 GREEN LINE RAPID TRANSIT CAR

LOADINGS:

Weight of Empty Car = 85,500 lbs
Max. Crush Load = 41,580 lbs
Actual Weight of Fully Loaded Car = 127,080 lbs
Rating Load For Fully Loaded Car = 129,000 lbs



#4 OVERHAULED BLUE LINE RAPID TRANSIT CAR ON ORANGE LINE

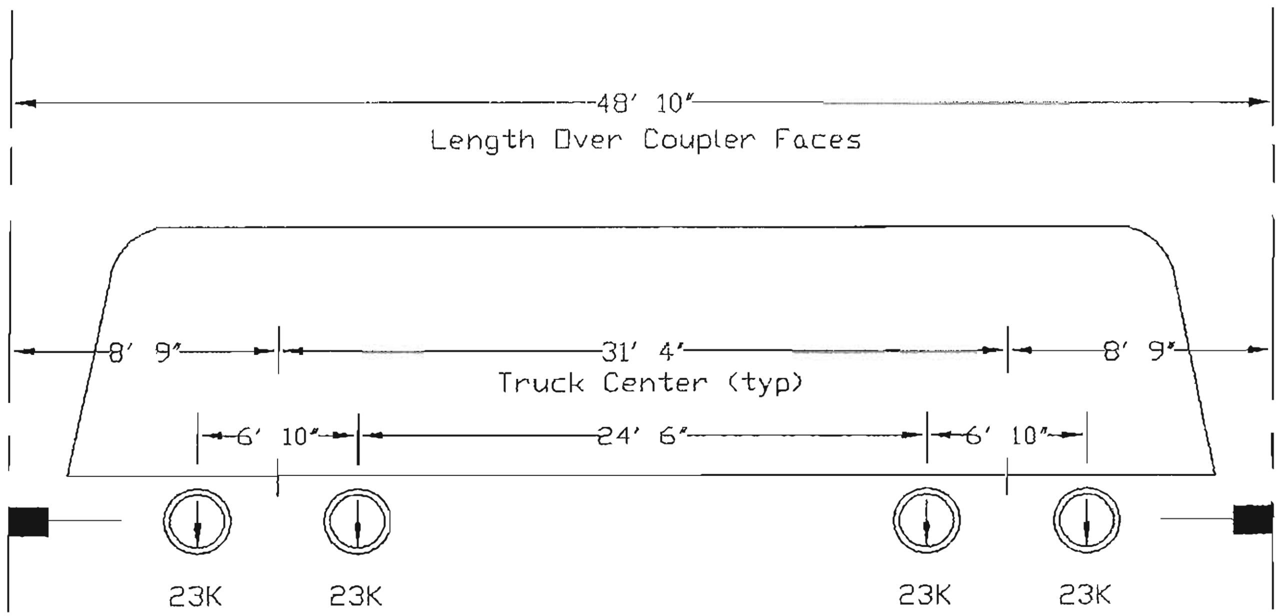
LOADINGS:

Empty Vehicle = 60,800 lbs

Max. Crush Load = 24,645 lbs

Actual Weight of Fully Loaded Loaded Car = 85,445 lbs

Design/Rating Load for Fully Loaded Car = 86,000 lbs



#5 BLUE LINE RAPID TRANSIT CAR

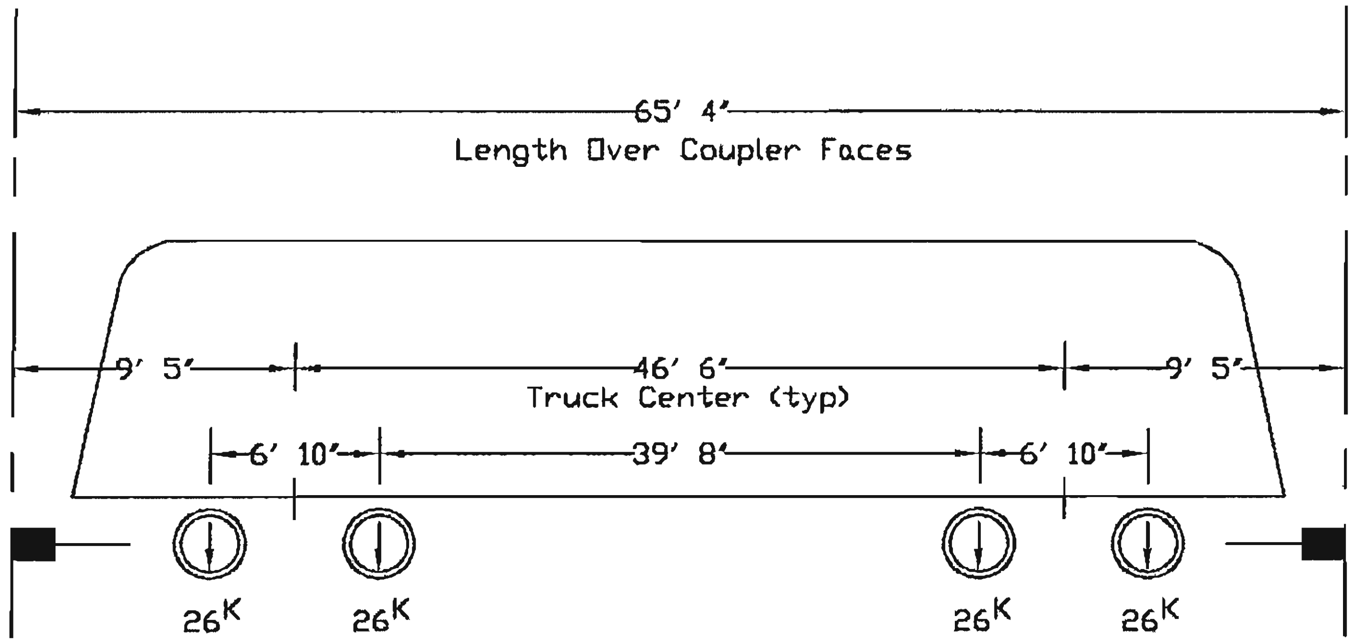
LOADINGS:

Empty Vehicle = 69,000 lbs

Max. Crush Load = 22,630 lbs

Actual Weight of Fully Loaded Car = 91,630 lbs

Rating Load for Fully Laoded Car = 92,000 lbs



#12 ORANGE LINE RAPID TRANSIT CAR

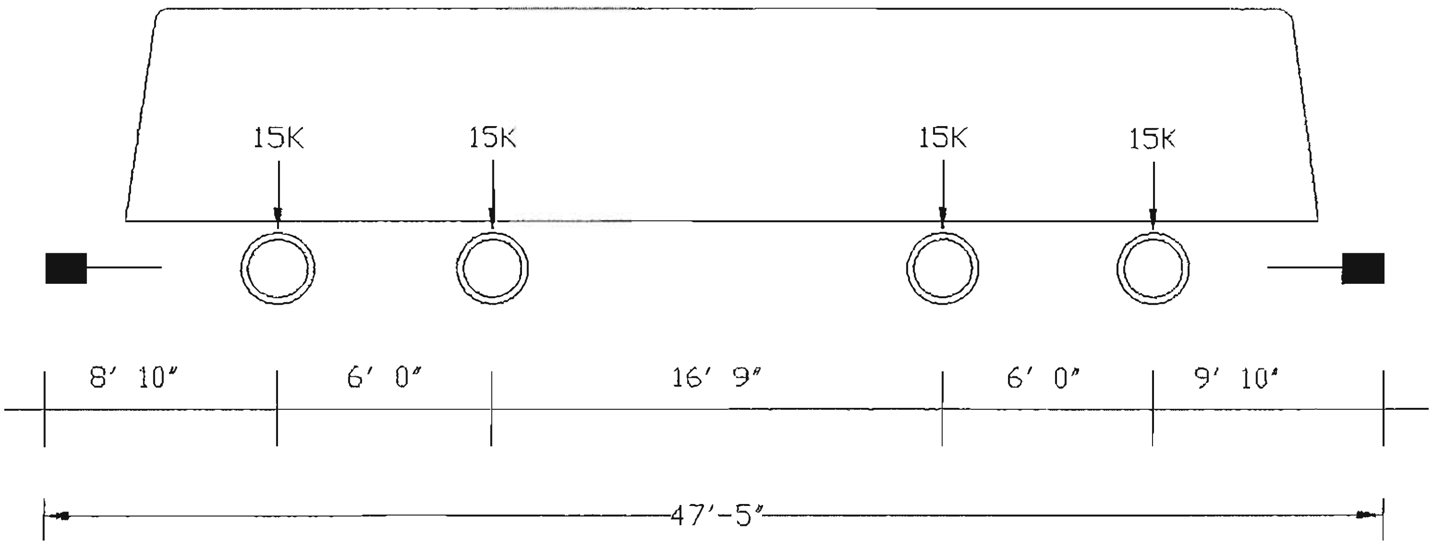
LOADINGS:

Empty Vehicle = 68,780 lbs

Max. Crush Load = 34,720 lbs

Actual Weight of Fully Loaded Car = 103,500 lbs

Rating Load for Fully Loaded Car= 104,000 lbs



PCC Car - High Speed Line

LOADINGS:

Weight of Empty Car = 40,035 lbs
Max Crush Load = 18,200 lbs
Actual Weight of Fully Loaded Car = 58,235 lbs
Rating Load for Fully Loaded Car = 60,000 lbs

#3 RED LINE RAIL TRANSIT CAR 4 AXLES @ 30 KIPS EA

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

(6 CARS)

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	30.00	AT SUPPORT	37.35	2.50
10.00	39.51	AT SUPPORT	75.00	5.00
15.00	46.34	AT SUPPORT	132.97	6.25
20.00	51.51	AT SUPPORT	206.23	11.67
25.00	59.21	AT SUPPORT	279.9	12.50
30.00	68.68	AT SUPPORT	390.30	15.00
35.00	76.01	AT SUPPORT	515.20	14.58
40.00	81.85	AT SUPPORT	661.70	23.33
45.00	85.89	AT SUPPORT	806.90	18.75
50.00	89.21	AT SUPPORT	953.40	29.17
55.00	92.01	AT SUPPORT	1098.60	22.92
60.00	94.34	AT SUPPORT	1243.60	25.00
65.00	96.31	AT SUPPORT	1389.60	37.92
70.00	98.08	AT SUPPORT	1536.70	29.17
75.00	101.54	AT SUPPORT	1685.10	37.50
80.00	105.82	AT SUPPORT	1835.10	40.00
85.00	110.18	AT SUPPORT	1985.10	42.50
90.00	114.51	AT SUPPORT	2135.10	45.00
95.00	119.54	AT SUPPORT	2285.10	47.50
100.00	125.41	AT SUPPORT	2435.10	50.00
105.00	130.87	AT SUPPORT	2607.45	52.50
110.00	135.83	AT SUPPORT	2827.18	64.17
115.00	140.36	AT SUPPORT	3044.98	47.92
120.00	144.51	AT SUPPORT	3266.48	50.00
125.00	148.33	AT SUPPORT	3542.90	72.92
130.00	151.86	AT SUPPORT	3835.20	54.17
135.00	155.12	AT SUPPORT	4126.20	78.75
140.00	158.22	AT SUPPORT	4418.50	58.33
145.00	162.08	AT SUPPORT	4709.50	84.58
150.00	166.38	AT SUPPORT	5001.80	62.50

NOTE: Distance X refers to distance from left support.
Impact is not included

#7 GREEN LINE RAIL TRANSIT CAR 6 AXLES, 4 @ 24 KIPS , 2 @ 16.5 KIPS

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

(3 CARS)

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	24.00	AT SUPPORT	28.00	2.92
10.00	33.00	AT SUPPORT	60.00	5.00
15.00	38.00	AT SUPPORT	111.50	8.75
20.00	40.50	AT SUPPORT	169.50	8.33
25.00	43.32	AT SUPPORT	227.50	14.58
30.00	47.26	AT SUPPORT	285.50	17.50
35.00	52.08	AT SUPPORT	347.25	17.50
40.00	55.69	AT SUPPORT	431.81	20.00
45.00	59.46	AT SUPPORT	522.72	26.25
50.00	63.12	AT SUPPORT	621.97	20.83
55.00	67.72	AT SUPPORT	721.22	32.08
60.00	72.83	AT SUPPORT	836.06	30.00
65.00	77.15	AT SUPPORT	989.44	32.50
70.00	80.85	AT SUPPORT	1154.44	35.00
75.00	84.38	AT SUPPORT	1311.94	37.50
80.00	88.67	AT SUPPORT	1476.94	40.00
85.00	93.80	AT SUPPORT	1634.44	42.50
90.00	98.42	AT SUPPORT	1815.56	45.00
95.00	102.55	AT SUPPORT	2022.94	47.50
100.00	106.77	AT SUPPORT	2246.06	50.00
105.00	111.18	AT SUPPORT	2475.75	52.50
110.00	115.67	AT SUPPORT	2721.56	55.00
115.00	119.77	AT SUPPORT	2965.50	57.50
120.00	123.53	AT SUPPORT	3228.00	60.00
125.00	127.95	AT SUPPORT	3490.50	62.50
130.00	132.72	AT SUPPORT	3753.00	65.00
135.00	132.72	AT SUPPORT	3753.00	65.00
140.00	141.67	AT SUPPORT	4305.00	70.00
145.00	145.68	AT SUPPORT	4594.50	72.50
150.00	149.42	AT SUPPORT	4902.00	75.00

NOTE: Distance X refers to distance from left support.
Impact is not included

#4 0VERHAULED BLUE LINE CAR ON ORANGE LINE
4 AXLES @ 21.5 KIPS EA

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

(8 CARS)

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	21.50	AT SUPPORT	26.77	2.50
10.00	28.32	AT SUPPORT	53.75	5.00
15.00	33.21	AT SUPPORT	95.37	6.25
20.00	38.28	AT SUPPORT	147.83	11.67
25.00	44.08	AT SUPPORT	214.89	12.50
30.00	51.07	AT SUPPORT	295.52	15.00
35.00	56.06	AT SUPPORT	393.06	14.58
40.00	59.80	AT SUPPORT	497.98	23.33
45.00	62.71	AT SUPPORT	602.11	18.75
50.00	65.54	AT SUPPORT	707.03	29.17
55.00	69.35	AT SUPPORT	811.16	22.92
60.00	74.08	AT SUPPORT	916.08	35.00
65.00	78.30	AT SUPPORT	1033.72	32.50
70.00	83.05	AT SUPPORT	1168.10	35.00
75.00	88.06	AT SUPPORT	1313.81	43.75
80.00	93.30	AT SUPPORT	1471.19	46.67
85.00	97.94	AT SUPPORT	1634.73	35.42
90.00	102.05	AT SUPPORT	1838.25	52.50
95.00	105.73	AT SUPPORT	2046.87	55.42
100.00	109.55	AT SUPPORT	2256.35	58.33
105.00	113.64	AT SUPPORT	2465.05	61.25
110.00	118.25	AT SUPPORT	2696.53	55.00
115.00	122.46	AT SUPPORT	2958.29	57.50
120.00	127.18	AT SUPPORT	3232.31	60.00
125.00	132.07	AT SUPPORT	3527.94	62.50
130.00	136.91	AT SUPPORT	3823.56	65.00
135.00	141.39	AT SUPPORT	4131.87	67.50
140.00	145.56	AT SUPPORT	4454.37	70.00
145.00	149.44	AT SUPPORT	4776.87	72.50
150.00	153.55	AT SUPPORT	5099.37	75.00

NOTE: Distance X refers to distance from left support.
Impact is not included

#5 BLUE LINE CAR 4 AXLES @ 23 KIPS EA

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

(6 CARS)

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	23.00	AT SUPPORT	28.75	2.50
10.00	30.29	AT SUPPORT	57.5	5.00
15.00	35.53	AT SUPPORT	101.99	6.35
20.00	41.02	AT SUPPORT	158.14	11.67
25.00	47.23	AT SUPPORT	230.00	12.50
30.00	54.69	AT SUPPORT	316.25	15.00
35.00	60.02	AT SUPPORT	420.40	14.58
40.00	64.02	AT SUPPORT	532.80	16.67
45.00	67.13	AT SUPPORT	644.04	18.75
50.00	70.15	AT SUPPORT	756.43	29.17
55.00	74.23	AT SUPPORT	867.67	22.92
60.00	79.29	AT SUPPORT	980.07	35.00
65.00	83.81	AT SUPPORT	1105.96	32.50
70.00	88.88	AT SUPPORT	1249.71	35.00
75.00	94.25	AT SUPPORT	1405.36	31.25
80.00	99.86	AT SUPPORT	1573.95	46.67
85.00	104.81	AT SUPPORT	1748.77	35.42
90.00	109.21	AT SUPPORT	1966.65	52.50
95.00	113.15	AT SUPPORT	2189.52	39.58
100.00	117.23	AT SUPPORT	2413.77	41.67
105.00	121.62	AT SUPPORT	2636.95	61.25
110.00	126.54	AT SUPPORT	2884.77	55.00
115.00	131.04	AT SUPPORT	3164.69	57.50
120.00	136.09	AT SUPPORT	3457.82	60.00
125.00	141.32	AT SUPPORT	3774.18	62.50
130.00	146.50	AT SUPPORT	4090.32	65.00
135.00	151.30	AT SUPPORT	4420.14	67.50
140.00	155.75	AT SUPPORT	4765.14	70.00
145.00	159.90	AT SUPPORT	5110.14	72.50
150.00	164.31	AT SUPPORT	5455.14	75.00

NOTE: Distance X refers to distance from left support.
Impact is not included

#12 ORANGE LINE CAR 4 AXLES @ 26 KIPS EA

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

(6 CARS)

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	26.00	AT SUPPORT	32.50	2.50
10.00	34.24	AT SUPPORT	65.00	5.00
15.00	40.16	AT SUPPORT	115.29	6.25
20.00	44.64	AT SUPPORT	178.77	11.67
25.00	51.31	AT SUPPORT	242.71	12.50
30.00	59.52	AT SUPPORT	340.21	15.00
35.00	65.87	AT SUPPORT	446.51	14.58
40.00	70.64	AT SUPPORT	573.47	16.67
45.00	74.35	AT SUPPORT	699.31	18.75
50.00	77.31	AT SUPPORT	826.28	29.17
55.00	79.74	AT SUPPORT	952.03	22.92
60.00	81.76	AT SUPPORT	1079.09	25.00
65.00	83.47	AT SUPPORT	1204.84	27.08
70.00	86.67	AT SUPPORT	1331.81	29.17
75.00	90.54	AT SUPPORT	1460.42	37.50
80.00	94.63	AT SUPPORT	1590.42	40.00
85.00	98.50	AT SUPPORT	1720.42	42.50
90.00	103.14	AT SUPPORT	1850.42	45.00
95.00	108.39	AT SUPPORT	1993.42	47.50
100.00	113.37	AT SUPPORT	2168.55	41.67
105.00	117.87	AT SUPPORT	2357.14	43.75
110.00	121.97	AT SUPPORT	2547.72	64.17
115.00	125.71	AT SUPPORT	2759.90	67.08
120.00	129.14	AT SUPPORT	3013.31	50.00
125.00	132.29	AT SUPPORT	3265.43	72.92
130.00	135.21	AT SUPPORT	3518.84	54.17
135.00	138.74	AT SUPPORT	3771.04	78.75
140.00	142.61	AT SUPPORT	4024.37	58.33
145.00	146.65	AT SUPPORT	4276.57	84.58
150.00	150.02	AT SUPPORT	4565.47	75.00

NOTE: Distance X refers to distance from left support.
Impact is not included

ASHMONT-MATTAPAN HSL PCC CAR 4 AXLES @ 15 KIPS EA

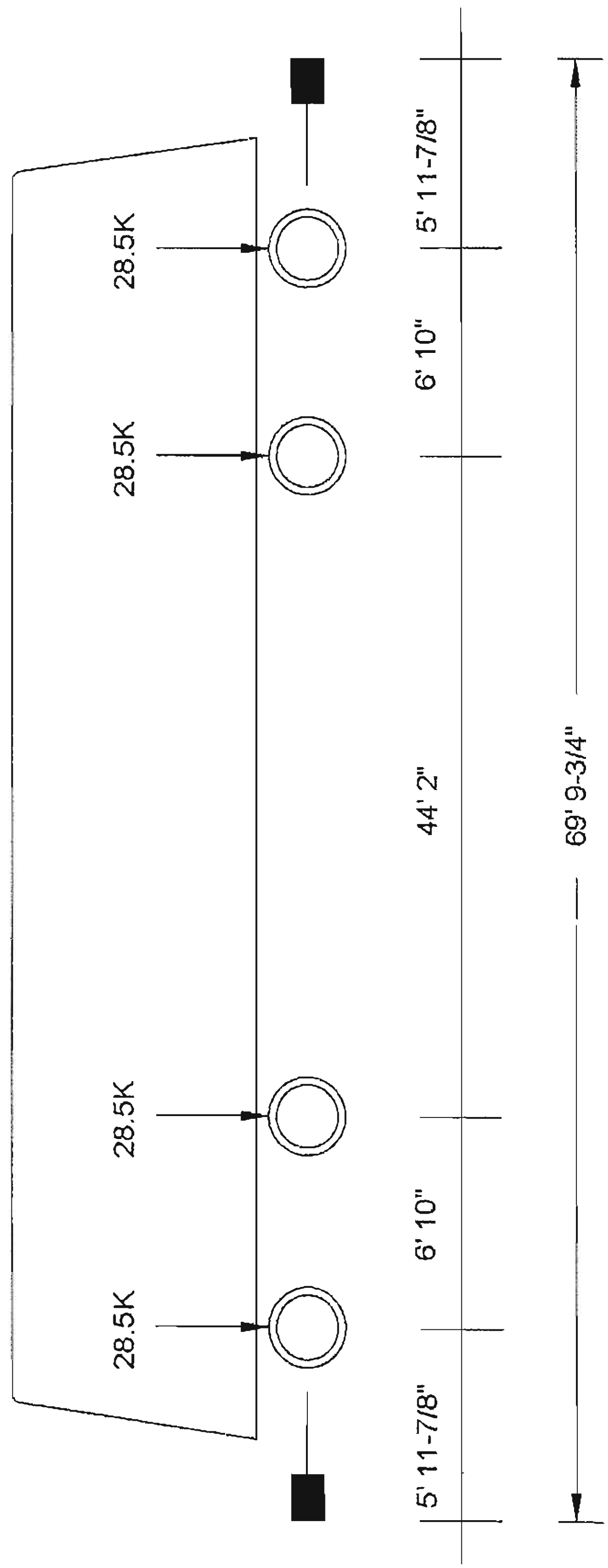
MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

(2 CARS)

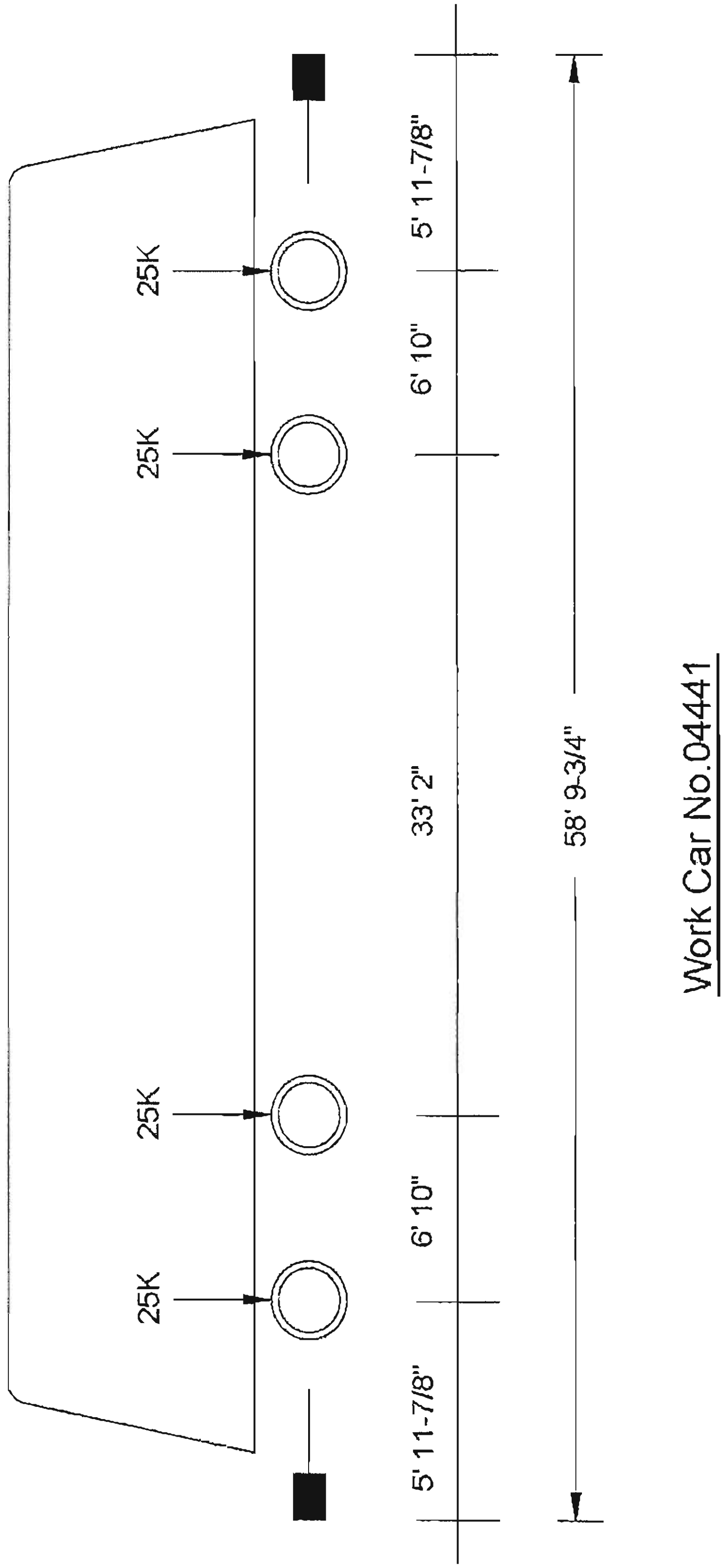
SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	14.49	AT SUPPORT	18.75	2.50
10.00	20.49	AT SUPPORT	37.50	5.00
15.00	23.66	AT SUPPORT	71.87	8.75
20.00	25.25	AT SUPPORT	108.33	8.33
25.00	26.99	AT SUPPORT	144.75	14.58
30.00	30.41	AT SUPPORT	181.25	17.50
35.00	34.64	AT SUPPORT	225.00	14.58
40.00	37.81	AT SUPPORT	283.12	23.33
45.00	40.83	AT SUPPORT	356.88	18.75
50.00	43.52	AT SUPPORT	429.77	20.83
55.00	46.81	AT SUPPORT	504.37	27.50
60.00	50.41	AT SUPPORT	598.12	30.00
53.46	60.59	AT SUPPORT	706.20	32.50
70.00	56.07	AT SUPPORT	818.70	35.00
75.00	59.30	AT SUPPORT	931.20	37.50
80.00	62.87	AT SUPPORT	1043.70	40.00
85.00	66.23	AT SUPPORT	1163.70	42.50
90.00	69.22	AT SUPPORT	1295.35	37.50
95.00	71.89	AT SUPPORT	1441.55	39.58
100.00	74.30	AT SUPPORT	1587.00	58.33
105.00	76.47	AT SUPPORT	1733.25	61.25
110.00	78.45	AT SUPPORT	1878.25	64.17
115.00	80.26	AT SUPPORT	2027.40	57.40
120.00	81.91	AT SUPPORT	2177.40	60.00
125.00	83.44	AT SUPPORT	2327.40	62.50
130.00	84.84	AT SUPPORT	2477.40	65.00
135.00	86.15	AT SUPPORT	2627.40	67.50
140.00	87.35	AT SUPPORT	2777.40	70.00
145.00	88.48	AT SUPPORT	2927.40	72.50
150.00	89.53	AT SUPPORT	3077.40	75.00

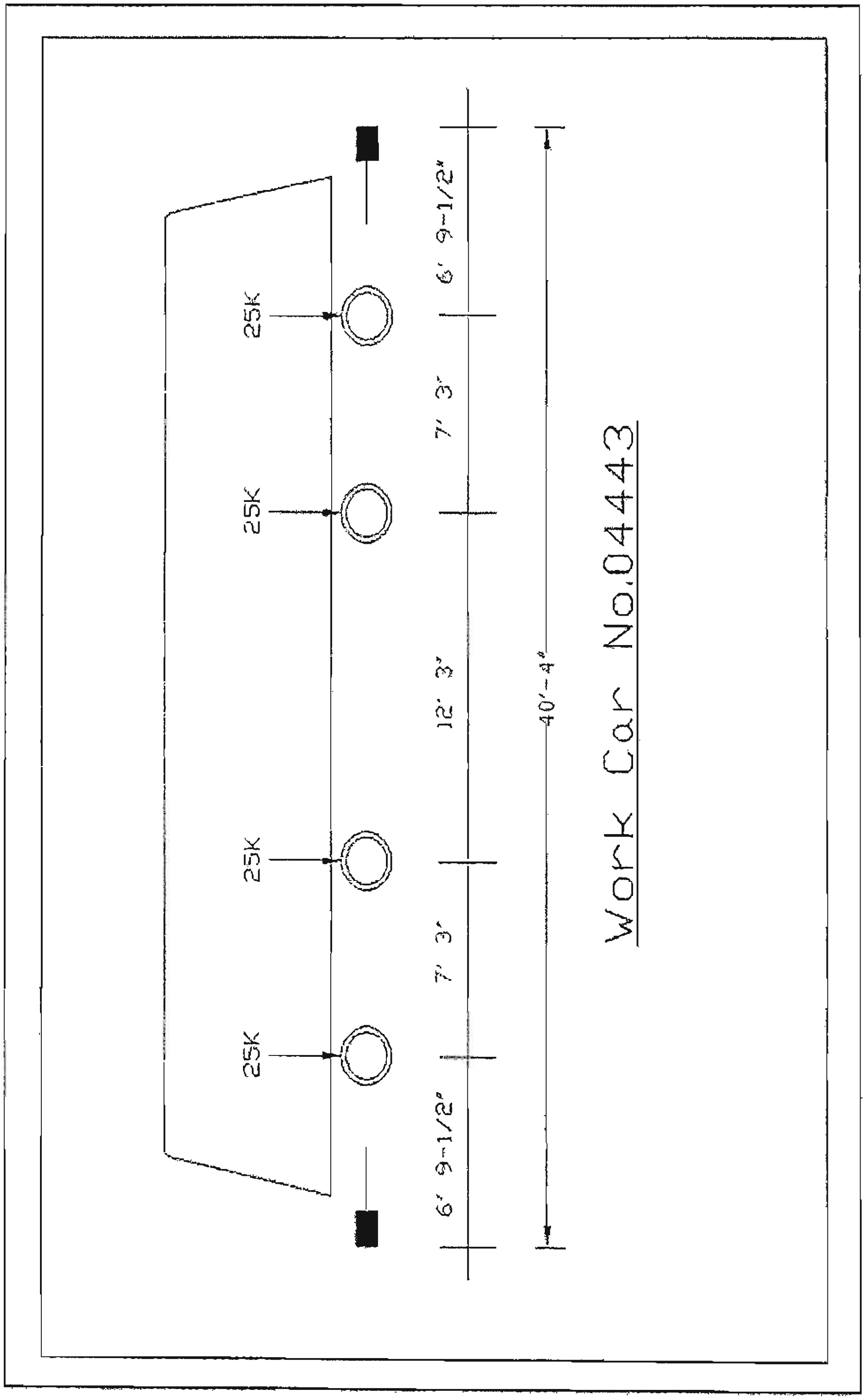
NOTE: Distance X refers to distance from left support.
Impact is not included

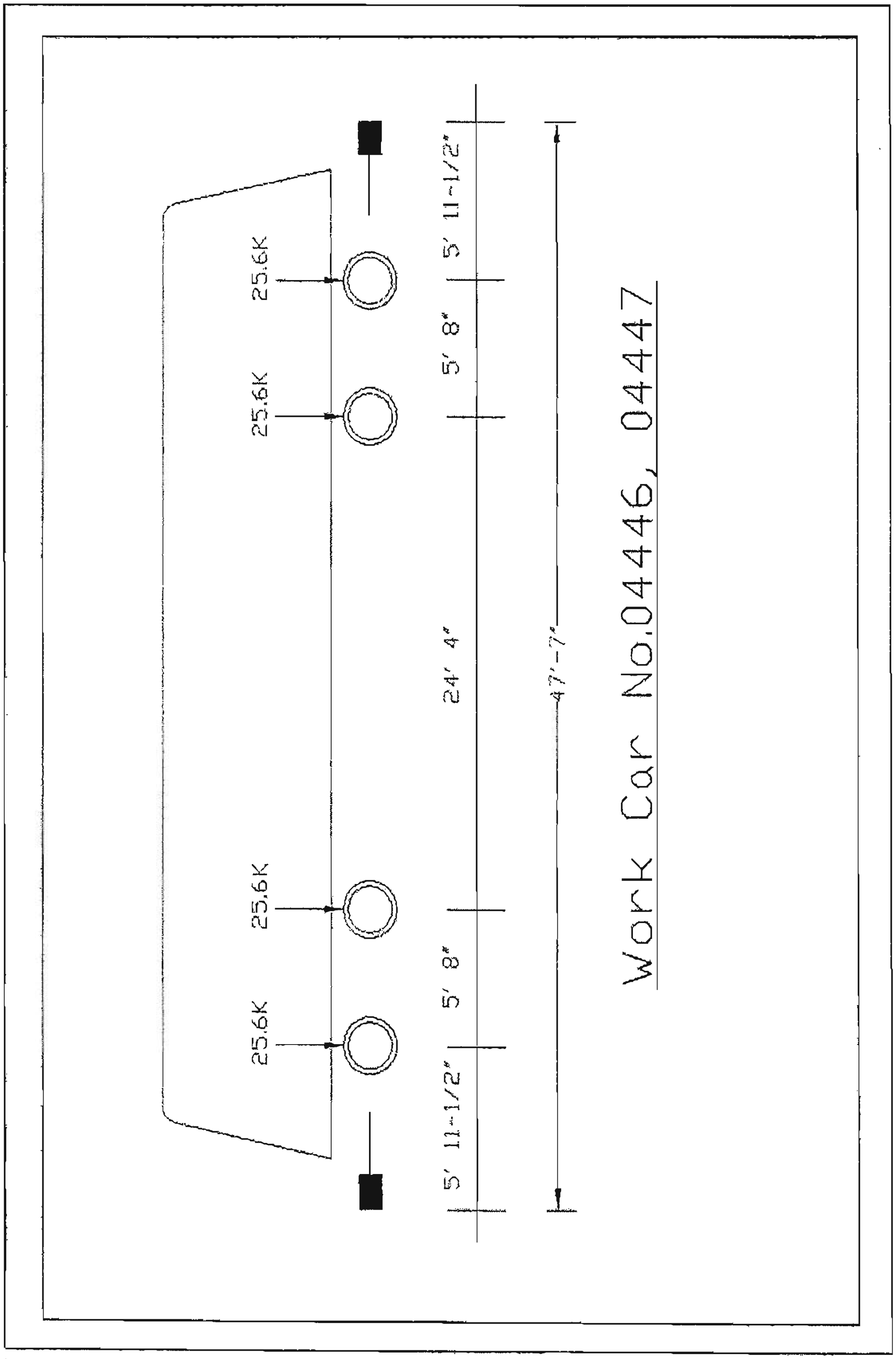
APPENDIX B
Work Car Configurations

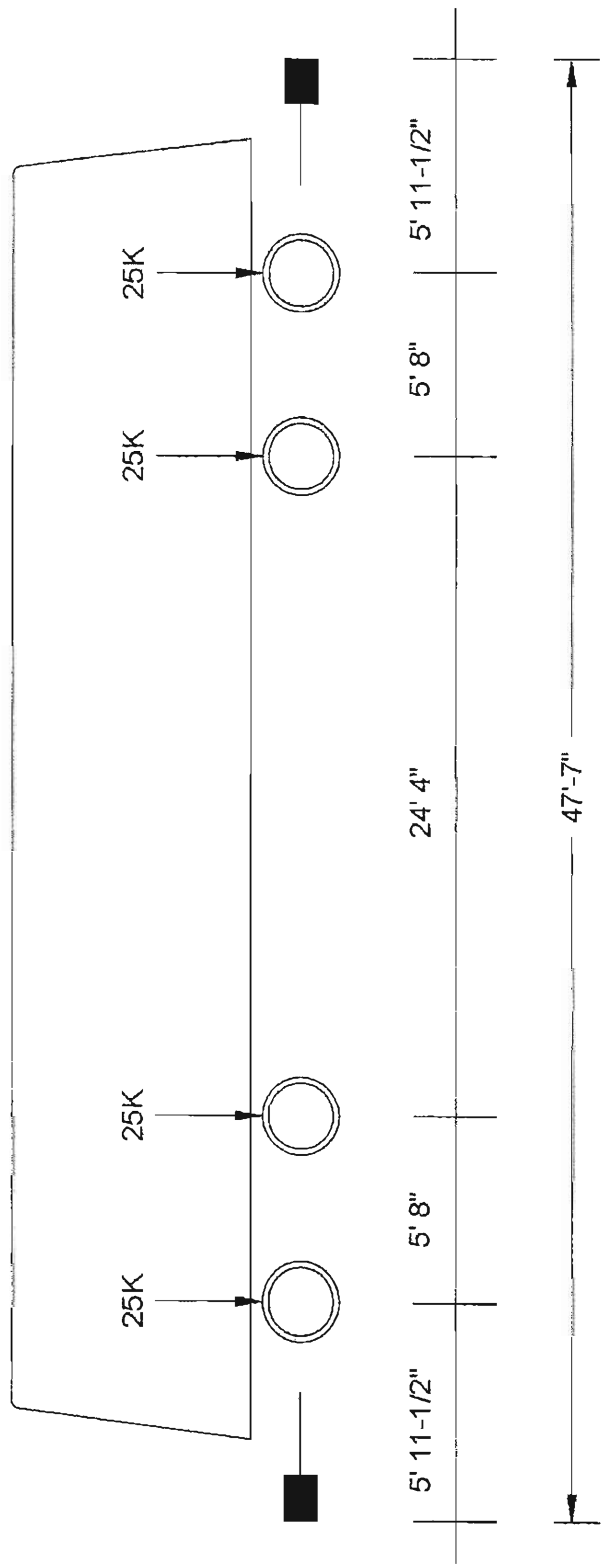


Work Motor Car 01400

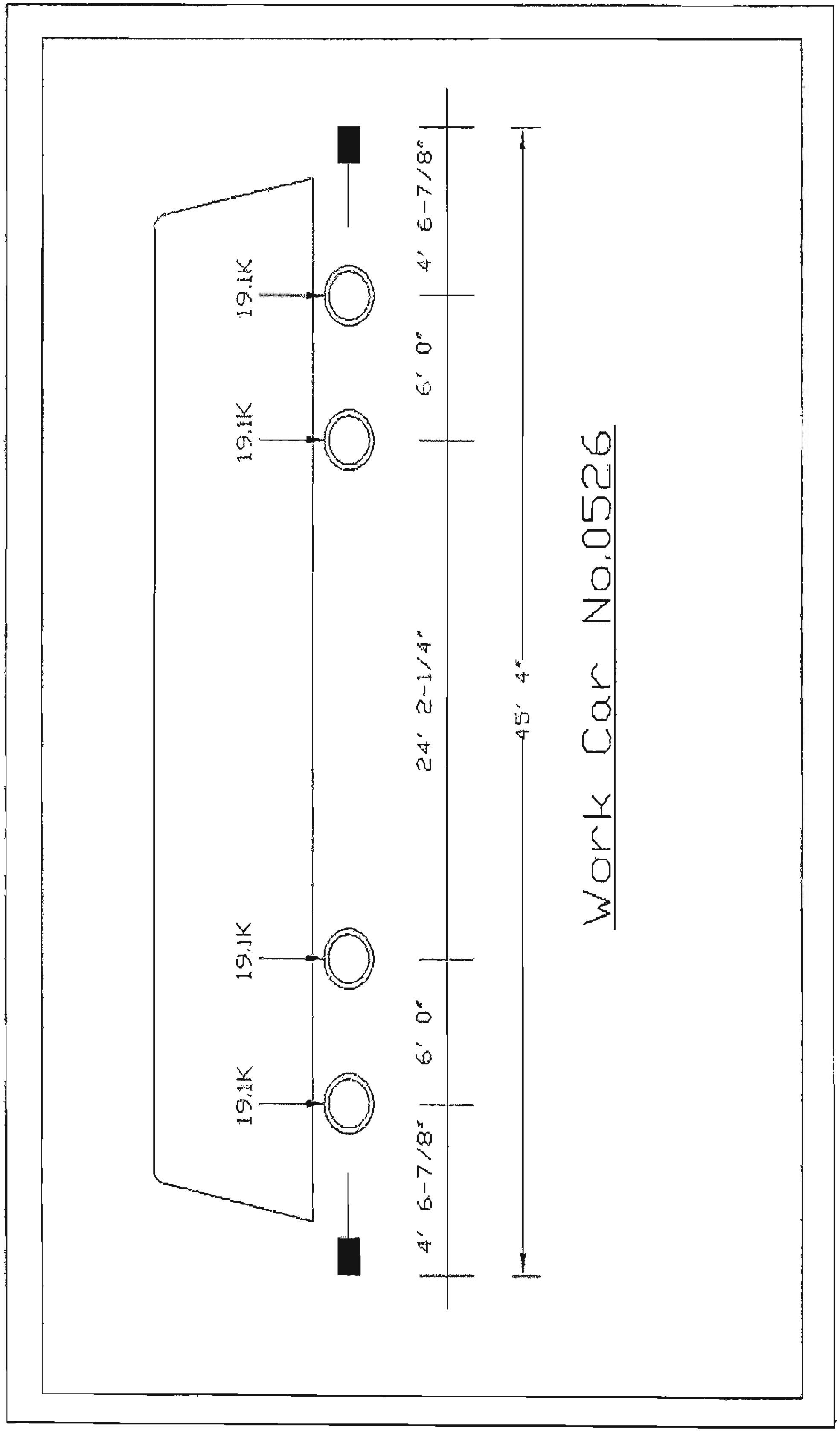

25K
25K
25K
25K
5' 11-7/8"
6' 10"
33' 2"
6' 10"
5' 11-7/8"
58' 9-3/4"
Work Car No.04441

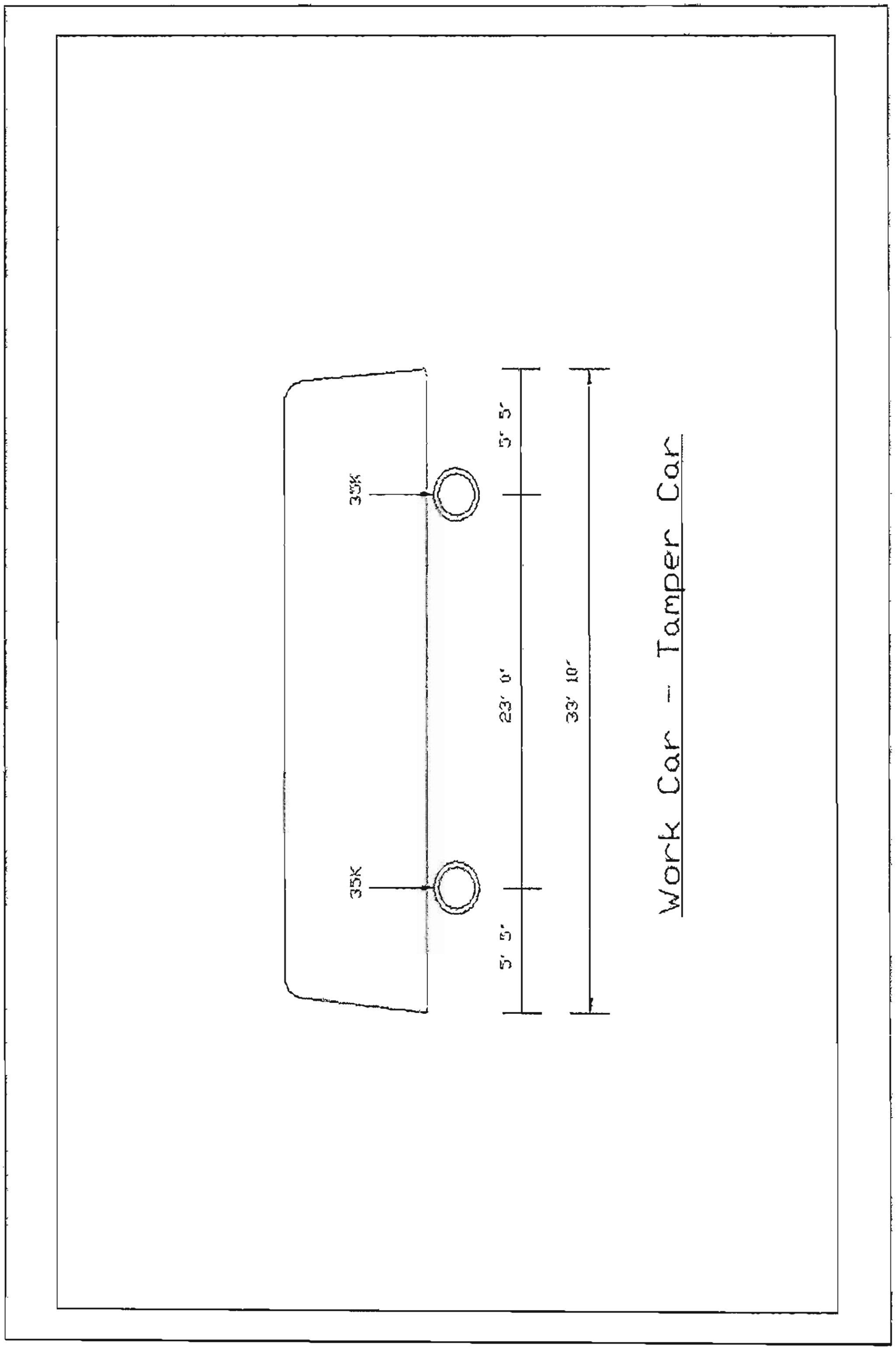

Work Car No.04443
25K
25K
25K
25K
6' 9-1/2"
7' 3"
12' 3"
7' 3"
6' 9-1/2"
40'-4"

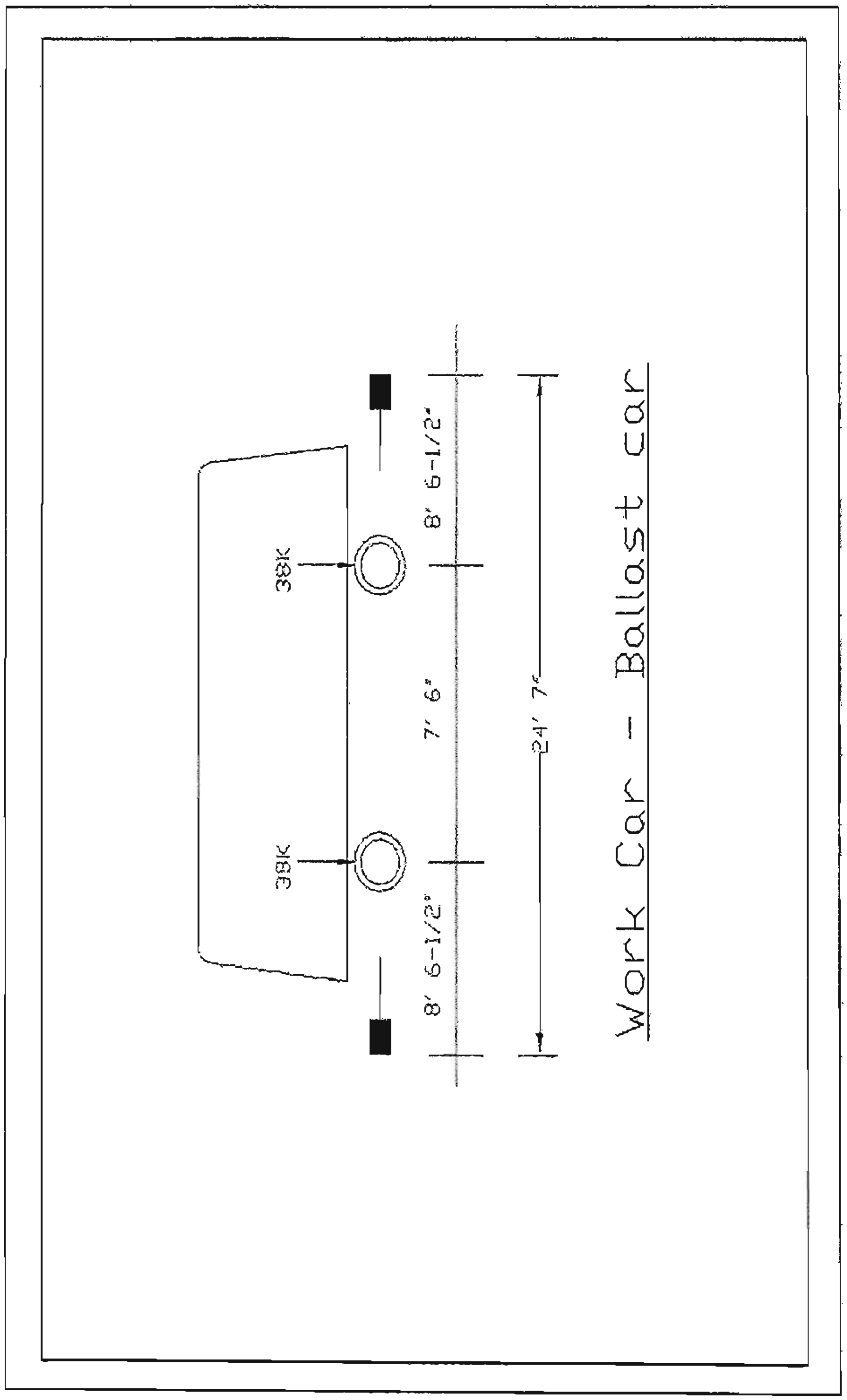

Work Car No.04446, 04447
25.6K
25.6K
25.6K
25.6K
5' 11-1/2"
5' 8"
24' 4"
5' 8"
5' 11-1/2"
47'-7"



Work Car No.04449


19.1K
19.1K
19.1K
19.1K
4' 6-7/8"
6' 0"
24' 2-1/4"
6' 0"
4' 6-7/8"
45' 4"
Work Car No.0526


Work Car - Tamper Car
35K
35K
5' 5'
23' 0'
5' 5'
33' 10'


38K
38K
8' 6-1/2"
7' 6"
8' 6-1/2"
24' 7"
Work Car - Ballast car

APPENDIX C

WORK CAR LOAD TABLES

NOTE:

The following moment, shear and reaction tables are provided only as a guide. See Appendix B for description of Work Vehicles.

Note for most simple spans to 150 feet, Work Car Combination V governs for both shear and moment.

Each individual case should be verified by the rating engineer.

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

Work Car Consist No I = 1 Loco (04443) + 2 Ballast + 1 Tamper

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	35.42	AT SUPPORT	46.11	2.92
10.00	46.89	AT SUPPORT	93.48	5.00
15.00	56.59	AT SUPPORT	157.76	8.75
20.00	61.45	AT SUPPORT	250.48	8.33
25.00	68.85	AT SUPPORT	342.95	10.42
30.00	75.87	AT SUPPORT	442.90	15.00
35.00	81.99	AT SUPPORT	581.65	17.50
40.00	90.74	AT SUPPORT	720.40	20.00
45.00	97.55	AT SUPPORT	859.15	22.50
50.00	105.71	AT SUPPORT	1025.11	25.00
55.00	113.10	AT SUPPORT	1258.86	27.50
60.00	119.26	AT SUPPORT	1492.61	30.00
65.00	124.47	AT SUPPORT	1726.36	32.50
70.00	130.72	AT SUPPORT	1960.11	35.00
75.00	137.30	AT SUPPORT	2193.86	37.50
80.00	144.47	AT SUPPORT	2467.70	40.00
85.00	150.80	AT SUPPORT	2767.07	42.50
90.00	156.42	AT SUPPORT	3094.57	45.00
95.00	161.45	AT SUPPORT	3422.07	47.50
100.00	165.98	AT SUPPORT	3755.82	50.00
105.00	171.35	AT SUPPORT	4114.57	52.50
110.00	176.60	AT SUPPORT	4473.32	55.00
115.00	181.40	AT SUPPORT	4832.07	57.50
120.00	185.80	AT SUPPORT	5190.82	60.00
125.00	189.95	AT SUPPORT	5564.97	62.50
130.00	193.59	AT SUPPORT	5967.47	65.00
135.00	197.05	AT SUPPORT	6369.97	67.50
140.00	200.26	AT SUPPORT	6772.47	70.00
145.00	203.25	AT SUPPORT	7174.97	72.50
150.00	206.04	AT SUPPORT	7577.47	75.00

NOTE: Distance X refers to distance from left support.
Impact is not included

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

Work Car Consist No II = 2 Flat Cars (04446 + 04447) + 1 Flat Car w/Crane (04441)

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	24.80	AT SUPPORT	31.25	2.50
10.00	35.37	AT SUPPORT	63.83	3.33
15.00	40.55	AT SUPPORT	123.19	6.25
20.00	45.55	AT SUPPORT	183.98	8.33
25.00	52.52	AT SUPPORT	248.75	10.42
30.00	60.43	AT SUPPORT	341.50	15.00
35.00	66.09	AT SUPPORT	459.17	14.58
40.00	70.32	AT SUPPORT	582.08	23.33
45.00	74.15	AT SUPPORT	703.00	26.25
50.00	77.94	AT SUPPORT	832.92	20.83
55.00	83.01	AT SUPPORT	946.67	22.92
60.00	88.59	AT SUPPORT	1067.50	25.00
65.00	93.32	AT SUPPORT	1215.38	32.50
70.00	99.08	AT SUPPORT	1377.65	40.83
75.00	105.12	AT SUPPORT	1559.90	31.25
80.00	111.05	AT SUPPORT	1743.15	33.33
85.00	116.29	AT SUPPORT	1945.25	49.58
90.00	120.94	AT SUPPORT	2183.37	52.50
95.00	123.10	AT SUPPORT	2427.12	55.42
100.00	128.84	AT SUPPORT	2670.88	58.33
105.00	132.21	AT SUPPORT	2930.38	52.50
110.00	137.57	AT SUPPORT	3219.63	55.00
115.00	142.45	AT SUPPORT	3532.13	57.50
120.00	146.94	AT SUPPORT	3844.63	60.00
125.00	151.06	AT SUPPORT	4157.13	62.50
130.00	154.86	AT SUPPORT	4469.63	65.00
135.00	158.39	AT SUPPORT	4782.13	67.50
140.00	161.66	AT SUPPORT	5094.63	70.00
145.00	164.71	AT SUPPORT	5407.13	72.50
150.00	167.55	AT SUPPORT	5719.63	75.00

NOTE: Distance X refers to distance from left support.
Impact is not included

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM
Work Car Consist No III = 1 Locomotive (04443) +1 Flat Car (0526)

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	24.60	AT SUPPORT	30.33	2.92
10.00	31.87	AT SUPPORT	62.50	5.00
15.00	37.91	AT SUPPORT	106.77	6.25
20.00	41.56	AT SUPPORT	167.19	8.33
25.00	48.25	AT SUPPORT	230.37	12.50
30.00	55.41	AT SUPPORT	315.62	15.00
35.00	61.78	AT SUPPORT	414.06	20.42
40.00	67.46	AT SUPPORT	534.38	16.67
45.00	73.58	AT SUPPORT	674.65	22.50
50.00	80.04	AT SUPPORT	824.30	25.00
55.00	85.33	AT SUPPORT	1000.00	27.50
60.00	89.73	AT SUPPORT	1169.80	30.00
65.00	93.46	AT SUPPORT	1345.50	32.50
70.00	97.12	AT SUPPORT	1515.30	35.00
75.00	101.31	AT SUPPORT	1691.00	37.50
80.00	106.00	AT SUPPORT	1860.80	40.00
85.00	110.14	AT SUPPORT	2036.50	42.50
90.00	113.82	AT SUPPORT	2206.30	45.00
95.00	117.12	AT SUPPORT	2395.13	47.50
100.00	120.08	AT SUPPORT	2613.12	50.00
105.00	122.76	AT SUPPORT	2833.27	52.50
110.00	125.20	AT SUPPORT	3054.12	55.00
115.00	127.43	AT SUPPORT	3274.27	57.50
120.00	129.47	AT SUPPORT	3495.12	60.00
125.00	131.35	AT SUPPORT	3715.27	62.50
130.00	133.08	AT SUPPORT	3936.12	65.00
135.00	134.68	AT SUPPORT	4156.27	67.50
140.00	136.17	AT SUPPORT	4377.12	70.00
145.00	137.56	AT SUPPORT	4597.27	72.50
150.00	138.85	AT SUPPORT	4818.12	75.00

NOTE: Distance X refers to distance from left support. Impact is not included

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

Work Car Consist No IV = 1 Flat Car (04449) + 4 Work Motor Cars (01400)

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	28.50	AT SUPPORT	34.49	2.50
10.00	37.53	AT SUPPORT	71.25	5.00
15.00	44.02	AT SUPPORT	126.33	6.26
20.00	47.29	AT SUPPORT	195.20	8.33
25.00	56.29	AT SUPPORT	265.49	12.50
30.00	63.18	AT SUPPORT	368.22	15.00
35.00	72.28	AT SUPPORT	490.39	20.42
40.00	75.84	AT SUPPORT	629.28	16.67
45.00	81.55	AT SUPPORT	767.03	18.75
50.00	83.47	AT SUPPORT	904.78	20.83
55.00	87.45	AT SUPPORT	1044.43	32.08
60.00	91.78	AT SUPPORT	1180.28	25.00
65.00	94.38	AT SUPPORT	1319.93	37.92
70.00	101.10	AT SUPPORT	1459.49	35.00
75.00	102.73	AT SUPPORT	1609.62	37.50
80.00	108.08	AT SUPPORT	1807.62	40.00
85.00	109.11	AT SUPPORT	2005.62	42.50
90.00	113.52	AT SUPPORT	2200.12	45.00
95.00	114.16	AT SUPPORT	2394.62	47.50
100.00	117.87	AT SUPPORT	2592.62	50.00
105.00	124.41	AT SUPPORT	2790.62	52.50
110.00	127.48	AT SUPPORT	2895.12	55.00
115.00	133.42	AT SUPPORT	3179.62	57.50
120.00	135.86	AT SUPPORT	3377.62	60.00
125.00	140.99	AT SUPPORT	3575.62	62.50
130.00	144.62	AT SUPPORT	3813.80	65.00
135.00	147.43	AT SUPPORT	4076.49	67.50
140.00	153.64	AT SUPPORT	4366.54	58.33
145.00	155.82	AT SUPPORT	4696.96	60.42
150.00	161.47	AT SUPPORT	5027.38	62.50

NOTE: Distance X refers to distance from left support.
Impact is not included

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

Work Car Consist No V = 1 Loco (04443) + 4 Ballast cars

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	38.00	AT SUPPORT	47.50	2.50
10.00	47.50	AT SUPPORT	95.00	5.00
15.00	57.00	AT SUPPORT	158.33	10.00
20.00	61.75	AT SUPPORT	249.09	11.67
25.00	66.45	AT SUPPORT	342.95	10.42
30.00	73.36	AT SUPPORT	435.42	17.50
35.00	82.34	AT SUPPORT	548.63	17.50
40.00	91.04	AT SUPPORT	674.87	20.00
45.00	97.82	AT SUPPORT	833.47	26.25
50.00	104.53	AT SUPPORT	1019.16	20.83
55.00	111.27	AT SUPPORT	1213.34	27.50
60.00	119.05	AT SUPPORT	1448.94	30.00
65.00	127.43	AT SUPPORT	1694.42	32.50
70.00	134.62	AT SUPPORT	1979.42	35.00
75.00	141.46	AT SUPPORT	2264.42	37.50
80.00	149.10	AT SUPPORT	2550.54	40.00
85.00	157.51	AT SUPPORT	2866.79	42.50
90.00	165.65	AT SUPPORT	3183.05	45.00
95.00	172.93	AT SUPPORT	3516.50	47.50
100.00	180.25	AT SUPPORT	3896.21	50.00
105.00	187.54	AT SUPPORT	4307.46	52.50
110.00	195.10	AT SUPPORT	4722.97	55.00
115.00	202.01	AT SUPPORT	5165.47	57.50
120.00	209.09	AT SUPPORT	5607.96	60.00
125.00	216.16	AT SUPPORT	6050.46	62.50
130.00	223.38	AT SUPPORT	6492.97	65.00
135.00	230.07	AT SUPPORT	6949.59	67.50
140.00	236.28	AT SUPPORT	7454.59	70.00
145.00	242.07	AT SUPPORT	7959.59	72.50
150.00	247.46	AT SUPPORT	8464.59	75.00

NOTE: Distance X refers to distance from left support.
Impact is not included

MAXIMUM MOMENT AND SHEAR ON A SIMPLY SUPPORTED BEAM

Work Car Consist No VI = 1 Loco (04443) + 2 Ballast cars + 1 Loco (04443) + 2 Ballast + 1 Loco (04443) + 2 Ballast)

SPAN LENGTH (FT)	MAX SHEAR (K)	AT DISTANCE X (FT)	MAX. MOMENT (K-FT)	AT DISTANCE X (FT)
5.00	38.00	AT SUPPORT	47.50	2.50
10.00	47.50	AT SUPPORT	95.00	5.00
15.00	57.00	AT SUPPORT	158.33	10.00
20.00	61.75	AT SUPPORT	249.09	11.67
25.00	66.73	AT SUPPORT	342.95	10.42
30.00	73.66	AT SUPPORT	435.42	17.50
35.00	82.34	AT SUPPORT	549.50	17.50
40.00	91.04	AT SUPPORT	675.75	20.00
45.00	97.82	AT SUPPORT	833.47	26.25
50.00	104.53	AT SUPPORT	1019.16	20.83
55.00	111.27	AT SUPPORT	1214.21	27.50
60.00	118.83	AT SUPPORT	1435.46	30.00
65.00	125.23	AT SUPPORT	1686.84	32.50
70.00	131.82	AT SUPPORT	1939.34	35.00
75.00	138.45	AT SUPPORT	2191.84	37.50
80.00	145.54	AT SUPPORT	2445.58	40.00
85.00	151.80	AT SUPPORT	2731.34	42.50
90.00	157.59	AT SUPPORT	3046.34	45.00
95.00	164.56	AT SUPPORT	3365.71	47.50
100.00	171.97	AT SUPPORT	3717.08	50.00
105.00	179.40	AT SUPPORT	4094.59	52.50
110.00	186.16	AT SUPPORT	4472.09	55.00
115.00	192.63	AT SUPPORT	4849.59	57.50
120.00	199.85	AT SUPPORT	5234.58	60.00
125.00	207.54	AT SUPPORT	5643.33	62.50
130.00	215.10	AT SUPPORT	6053.60	65.00
135.00	222.09	AT SUPPORT	6520.48	67.50
140.00	229.14	AT SUPPORT	7014.26	70.00
145.00	236.18	AT SUPPORT	7518.01	72.50
150.00	243.44	AT SUPPORT	8032.38	75.00

NOTE: Distance X refers to distance from left support.
Impact is not included